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The University of Adelaide

REPORT

OF THE

WAITE AGRICULTURAL RESEARCH INSTITUTE

SOUTH AUSTRALIA

AND ASSOCIATED ACTIVITIES OF THE

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

1948-1949

COMMONWEALTH MYCOLOGICAL INSTITUTE
MAY 1952

ADELAIDE
AT THE HASSELL PRESS
1951

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The University of Adelaide

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The Waite Agricultural Research Institute

STAFF (at 31st December, 1949)

Director: J. A. PRESCOTT, C.B.E., D.Sc.

AGRICULTURAL CHEMISTRY:

Head of Department and Waite Professor of Agricultural Chemistry: J. A. PRESCOTT, C.B.E., D.Sc.
Senior Soil Chemist: C. S. PIPER, D.Sc.
Lecturer in Agricultural Chemistry: R. J. BEST, D.Sc.
Chemist: H. P. C. GALLUS, M.Sc.
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Laboratory Assistants: R. D. BOND, H. E. JONES.

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Head of Department and Waite Professor of Agronomy: H. C. TRUMBLE, M.Ag.Sc., D.Sc. (on leave).
Acting Head of Department and Grassland Ecologist: R. L. CROCKER, D.Sc.
Chief Assistant in Agronomy: K. WOODROFFE, B.Ag.Sc.
Assistant Agronomists: A. J. K. WALKER, B.Ag.Sc., N. S. Tiver, M.Sc., MARY A. TODD, B.Sc., HELEN M. FERRES, M.Sc.
Research Fellow: P. F. BUTLER, B.Ag.Sc.
Systematic Botanist: CONSTANCE M. EARDLEY, M.Sc. (part time). ENID L. ROBERTSON, B.Sc. (part time).
Technical Assistants: E. J. LEANEY, R. M. FEUERHEERDT.
Laboratory Assistants: JANET BARTHOLOMAEUS, NAOMI M. NUGENT, MARGARET E. JACKMAN.
Overseer at Yudnapinna Field Station: M. A. THORPE.

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Assistant Geneticist: G. M. E. MAYO, B.Ag.Sc. (Hons.).
Research Fellow in Cytology: K. ABELE, M.A., Ph.D.
Plant Breeder: B. HOROWITZ,* Eng. Agr.D.Ag.Sc. (Cracow).
Technical Assistant: S. R. HOCKLEY.
Laboratory Assistant: GERALDINE E. BROOKES.
U.N.E.S.C.O. Research Scholar: P. K. SHUKLA, M.Sc.

ENTOMOLOGY:

Head of Department: D. C. SWAN, M.Sc.
Entomologists: H. G. ANDREWARTHA, D.Sc., T. O. BROWNING, B.Sc.
Technical Assistant: HELEN M. BROOKES.
Laboratory Assistant: MARGARET E. MORPHETT.

* Seconded by C.S.I.R.O.

PLANT PATHOLOGY:

Head of Department: D. B. ADAM, B.Ag.Sc.
Plant Pathologist: N. T. FLENTJE, M.Sc. (on leave).
Research Fellow: B. W. HOLLOWAY, B.Sc.
Laboratory Assistants: JANET E. THOMSON, JOYCE MUXLOW.

PLANT PHYSIOLOGY:

Senior Plant Physiologist: F. L. MILTHORPE, M.Sc.Agr., Ph.D.
Laboratory Assistant: MARGARET M. FRANCIS.

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Clerk*: F. W. BLANKSBY.
Librarian: BETTY J. KINNEAR.
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FARM:

Manager: K. A. PIKE, R.D.A.
Foreman: A. W. DICK.

TEMPORARY AND VOLUNTARY WORKERS DURING 1948–1949:

R. N. ELSTON, W. W. FORREST, D. M. ALEXANDER, E. D. CARTER, G. R. SHIRPURKAR.

MEMBERS OF THE STAFF WHO HAVE LEFT FOR OTHER APPOINTMENTS SINCE 1ST JANUARY, 1948:

C. H. WILLIAMS, L. A. T. BALLARD, H. W. SIMMONDS, R. L. SPECHT.

* Appointed by C.S.I.R.O.

Commonwealth Scientific and Industrial Research Organization

Staff with Headquarters at the Waite Agricultural Research Institute (as at 31st December, 1949):

DIVISION OF SOILS:

Chief: J. K. TAYLOR, B.A., M.Sc., B.Sc.(Agr.).

Soil Physics Section:

Senior Research Officer: T. J. MARSHALL, M.Ag.Sc., Ph.D. (on leave).
Research Officers: G. D. AITCHISON, B.E., K. NORRISH, M.Sc., G. B. STIRK, B.Sc., J. P. QUIRK, B.Sc. (Agr.), C. G. GURR, B.Sc.
Technical Officer: A. W. PALM.
Technical Assistant: N. W. FORRESTER.
Assistants: F. R. PEDLER, J. G. PICKERING, L. A. G. AYLMORE.

Soil Chemistry Section:

Senior Research Chemist: C. S. PIPER, D.Sc. (part time).
Research Officers: A. C. OERTEL (Spectrography), M.Sc., J. T. HUTTON, B.Sc., H. C. T. STACE, B.Sc., B. M. TUCKER, B.Sc., R. S. BECKWITH, B.Sc., M. RAUPACH, B.Sc.
Technical Officers: A. R. P. CLARKE, A. D. HALDANE, B.Sc., R. M. TAVENDER.
Assistants: PATRICIA N. NOYES, JOAN F. HOBDEN, HELEN R. MENZ.

Soil Survey and Pedology Section:

Senior Research Officer: C. G. STEPHENS, D.Sc.
Research Officers: K. D. NICOLLS, B.Sc., B.Ag.Sc., K. H. NORTHCOTE, B.Ag.Sc., G. BLACKBURN, B.Ag.Sc., G. A. STEWART, B.Ag.Sc.
Cartographer: P. D. HOOPER.
Draughtsmen: R. B. EWERS, M. C. COULLS.

NOTE.—There are five Regional Centres—Brisbane, Hobart, Perth, Canberra and Deniliquin permanently staffed with research officers of the Soil Survey Section.

Soil Microbiology Section:

Research Officers: MARGARET P. READ, B.Sc., Ph.D. (on leave), J. R. HARRIS, B.Sc.
Assistant: BAYES LLOYD.

Guayule Rubber Investigations:

Research Officer (Chemist): R. E. SHAPTER, A.A.C.I.

Committee on Oenological Research:

(Chairman: Professor J. A. Prescott, C.B.E., D.Sc.)
Senior Research Officer: J. C. M. Fornachon, M.Sc.
Assistant: Nadia H. Bressler.

Division of Plant Industry:

Principal Plant Physiologist: L. A. T. Ballard, Ph.D., M.A., M.Ag.Sc.

Field Station: Division of Biochemistry and General Nutrition:

Technical Assistant: E. Talbot-Smith.

C.S.I.R.O. Officers who have left for other Appointments since 1st January, 1947:

Barbara R. Hardy, Shirley E. Correll, R. A. Perry, Judith Grace, W. K. Joklik.

The Waite Agricultural Research Institute

1. Introduction.

The foundation of the Waite Institute was made possible as a result of the gift of Peter Waite to the University of Adelaide of land and property at Glen Osmond, together with an endowment.

It was in October, 1913, that Mr. Waite first intimated to the University Council his desire to establish the Institute and from that time till his death in 1922 he took a personal interest in the scheme to be developed. In 1915 he purchased Netherby Estate (112 acres) and Claremont (53 acres) adjoining his estate of Urrbrae, making a total of 299 acres to be given to the University for the Institute, in addition to 114 acres to the South Australian Government for an Agricultural High School.

The landed estate came into possession of the University in 1922 and with it a number of shares in Elder, Smith & Co., Ltd., which realized the sum of £58,450. The total value was estimated at £100,000; the annual Government subsidy of five per cent. amounted to £5,000, and work began with an income of about £8,000.

In May, 1923, the University Council resolved that the estate be given a name that defines the function, namely, "The Waite Agricultural Research Institute." The first appointments to the staff were made in 1924 and 1925.

The University purchased 80 acres of the Springfield estate adjacent to Netherby in 1935 and 10 acres of Alverstoke in 1948 for the purposes of the Institute.

The three first laboratories were those endowed by the late Sir John Melrose, the family of the late John Darling and the family of the late Ranson Mortlock. A fourth laboratory was completed in 1947, with the assistance of an advance of £9,602 from the Commonwealth Government as part of the Rehabilitation Scheme for the education of ex-servicemen.

In addition to the laboratories, a range of glasshouses, two implement sheds, a woolshed, and a cereal barn have been erected since 1925. The glasshouses include two designed for general work in agronomy, plant pathology, and plant physiology and one designed for entomology.

Since 1927 the Division of Biochemistry and General Nutrition of the Commonwealth Scientific and Industrial Research Organization has maintained at the Waite Institute a field station equipped with feeding pens and a laboratory. Here certain problems in the nutrition of sheep, requiring relatively large numbers of animals, are investigated.

Since 1929 the Waite Institute has been the headquarters of the Division of Soils of the Commonwealth Scientific and Industrial Research Organization.

Endowments subsequent to the original one of Peter Waite have included those of the late Mrs. Elizabeth Macmeikan, and the late Mr. Hugh Hughes. The Ranson Mortlock Trust Fund was established in 1936 by the family of the late Mr. Frederick Ranson Mortlock for research in connection with the regeneration of pastoral lands in the more arid regions. Mr. J. T. Mortlock

subsequently generously supported these investigations with special donations and on his death in 1950 made financial provision for their continuation.

Apart from its original and subsequent endowments the Institute derives its main income from appropriations under Acts of Parliament of South Australia.

During 1949 an agreement of far-reaching importance and both immediate and long-term significance was reached between the University and the Minister of Agriculture about the relative functions of the Waite Institute and the State Department of Agriculture. Since its inception the Institute has provided certain scientific advisory services to the Department, and these services will be continued. But the agreement affects profoundly both the Institute and the Department. Broadly it defines the work of the Institute as fundamental research which aims to serve the needs of South Australian agriculture, and that of the Department as the advisory or extension work needed to promote the application of the results of such research in a practical way. Partly to meet the increased costs of its existing research work and partly to enable necessary developments and expansion, the Government substantially increased its annual grant to the University for the Institute.

In 1949 the Wool Research Trust Account granted £5,000 through the Commonwealth Scientific and Industrial Research Organization for the investigation of sheep pastures, including the control of certain weeds and the study of insect pests. Imperial Chemical Industries of Australia and New Zealand, Ltd. provided a post-graduate research scholarship tenable for three years at the Institute starting from 1950.

Under the original deed of gift it was provided that portion of the area containing 67 acres should be held in perpetuity as a public park. Effect has been given to this provision by the establishment of an arboretum in which trees can be grown to demonstrate their value for shelter and ornament, and their adaptability to the local soil and climate. More than 1,100 trees in all, belonging to 530 different species, have been planted since 1928.

The library of the Waite Institute is designed to meet the needs of research, and the policy is to make it as complete a reference library as possible on matters relating to the field of agricultural science. The present total of books is 2,600 and of bound periodicals 4,300, with an additional 40,000 serials and pamphlets.

From the beginning of 1925 until early in 1938 the Waite Institute was under the direction of Dr. A. E. V. Richardson, whose death in December, 1949, is recorded with deep regret. A graduate of Adelaide, he had had extensive experience in the Department of Agriculture in Victoria and in the University of Melbourne before being appointed to the joint office of Professor of Agriculture and Director of the Institute in 1924. His was the dominating influence in the original determination of the nature and scope of the scientific work to be pursued at the Institute. While still at the Institute, Dr. Richardson was appointed by the Commonwealth Government, a member of the Executive committee of the Council for Scientific and Industrial Research and in 1938 he accepted a full-time appointment as an Executive member of the Council of which he was Chief Executive Officer from 1946 to 1949. He was also a founder and first President (in 1935) of the Australian Institute of Agricultural Science. His work for the Waite Institute constitutes an enduring monument to his organizing ability.

Dr. L. A. T. Ballard, Plant Physiologist since 1946 resigned in 1949 to take up an appointment with the Division of Plant Industry of the Commonwealth Scientific and Industrial Research Organization. He has been succeeded by Dr. F. L. Milthorpe.

Professor H. C. Trumble has been granted leave from September, 1949, to accept an appointment as agronomist in the Food and Agriculture Organization of the United Nations until January, 1951.

During the two years under review experimental work has been conducted at country centres with the goodwill and co-operation of a number of individuals and organizations. It is a pleasure to record such assistance from the following: Messrs. F. Coleman & Sons, Saddleworth; The Yudnapinna Pastoral Company; Elder, Smith & Co., Ltd., Wool Department; Mrs. A. B. Kidman, Naracoorte; Mr. R. James, Lucindale; Mr. T. R. Paltridge, Lucindale; Mr. R. McDonald, Furner; Mr. T. N. Bell, Millicent; Mr. D. Heysen, Kalangadoo; Mr. R. Somerville, Penola; Mr. G. C. Cameron, Beachport; Mr. D. P. Gericke, Naracoorte; Mr. A. Major, Lochaber; Mr. P. Daw, Lucindale; Mr. Tapsfield, Kingston; Mr. McClaren, Kingston; Mr. H. Seager, Kingston; Messrs. James Bros., Meningie; Mr. F. R. Humphris, Jamestown; Mr. G. R. Schiller, Hammond; Mr. R. L. Davidson, Woodside; Mr. K. Miller, Springton.

2. Scientific Work of the Institute.

The scientific work of the Institute is centred round the study of the principles of crop and pasture husbandry, and of the problems which may be associated with this aspect of agriculture. Animal husbandry is not a feature of the work of the Institute except in so far as it is necessary for the study of pastures. The main subjects of investigation may be included in the following groups:

Agronomy and Agrostology.

The investigation of the factors affecting the production of farm crops and the improvement, establishment and management of pastures under the wide range of rainfall conditions prevailing in South Australia; the identification and control of weeds.

Genetics and Plant Breeding.

The investigation of the principles of inheritance in plants and their application in the improvement of agricultural and horticultural crops in South Australia.

Plant Physiology.

The investigation of factors concerned in the growth reactions of crop plants, with particular emphasis on their water relations.

Plant Pathology.

The investigation of the diseases of agricultural and horticultural crops and of forest trees.

Entomology.

The investigation of the insect pests of agricultural and horticultural crops, of stored products and of forest trees.

Agricultural Chemistry.

The classification of soils; the investigation of soil fertility problems; the chemical study of plant viruses; the chemical study of pastures.

As stated previously, the Waite Institute, in addition to its principal function of research, provides scientific advisory services in systematic botany, plant pathology and entomology to the Minister responsible for the Departments of Agriculture and of Woods and Forests. The University of Adelaide maintains a School of Agricultural Science and in conjunction with Roseworthy Agricultural College provides courses of instruction leading to the degree of B.Ag.Sc. Of these courses those in the third and fourth year in agriculture, agricultural chemistry, mycology, plant pathology and entomology are provided at the Waite Institute. Facilities are provided in the several departments for post-graduate training leading to the higher degrees.

The Work of the Institute

Agronomy and Agrostology

Since the commencement of the work of the Institute in 1925, crop rotation and fertilizer experiments have been conducted with a view to establishing principles for the maintenance of soil fertility in the wheatlands of South Australia. It was realized that soil fertility could not long be maintained under the narrow exploitative rotations of the fallow-wheat type which were commonly practised by farmers. The recent finding by the Division of Mathematical Statistics of C.S.I.R.O. that wheat yields are in fact declining in many districts of the State has given added importance to field experiments relating to this problem. A new rotation experiment has been laid down and alterations have been made to some of the older experiments to give more information on the effect of pasture leys on soil fertility. The conservation and efficient utilization of rainfall in the wheat belt, where the average seasonal precipitation is mainly below the optimum required for wheat production, is a related subject which is also receiving attention.

The programme of pasture investigations has continued to be centred in the lower South-East of South Australia. The grassland survey has been completed, and the pasture types have been defined in terms of botanical composition and of their edaphic, climatic, and developmental relationships. Problems of pasture establishment and mineral nutrition indicated by the survey have been the subjects of experimental study. In the arid north of the State, investigations on the management and regeneration of shrub pastures have been maintained.

In the field of weed ecology work has proceeded on Cape Tulip (*Homeria collina* and *H. miniata*) and in addition a study has been undertaken of Wild Onion (*Asphodelus fistulosus*), which has attained a widespread distribution in the semi-arid areas of South Australia.

1. Permanent Rotation Experiment.

The permanent rotation plots up to 1948 involved comparisons of eleven systems of crop rotation, the main features of which have been described in previous reports. The broadest of these rotations, which also has given the highest average yield of wheat, was the four-course rotation, fallow-wheat-oats-pasture. The pasture in this rotation is a mixture of oats and Wimmera ryegrass and does not include a legume. Since 1948 some of the older rotations have been discontinued to allow the inclusion of longer pasture leys based on subterranean clover in combination with Phalaris or Wimmera ryegrass. The new rotations are as follows: two years ley-wheat; two years ley-fallow-wheat; four years ley-two years wheat; and one permanent pasture plot.

It will be some time before the new rotations begin to yield results, and, therefore, in Table 1, page 40 only the yields of the older rotations which have been retained are given.

The most noteworthy feature in the last two seasons was the high yield of wheat in 1949 in the rotations which included one year of pasture. In the rotations wheat continuously, fallow-wheat, and fallow-wheat-oats yields appear to be declining although the length of record is not yet long enough for this to be shown conclusively. It has been found that the degree of water-stable aggregation of the soil in these rotations has declined by about 50 per cent. and that the infiltration rate of water into the soil of the fallow-wheat plots is only one-sixteenth of the rate for a soil recently fallowed after a long pasture ley.

2. Investigations of Forage Crops and Temporary Pasture in Four-Course Rotations with Wheat.

This experiment is designed to determine the value of different forage crops for maintaining soil fertility. The results to 1947 were given in some detail in the last report, after the completion of two full cycles of the four-course rotations. The original rotations were as follows:

A	*B*	*C*	*D*	*E*
Fallow	Fallow	Fallow	Fallow	Fallow
Wheat	Wheat	Wheat	Wheat	Wheat
Peas	Clover	Barley	Oats	Fallow
Pasture	Pasture	Pasture	Pasture	Wheat

Superphosphate was applied to all crops and to the pasture. Half of each plot sown to forage was harvested each year and the produce removed whilst the other half plot was grazed. The pasture which consisted of Wimmera ryegrass was grazed twice each season, yields being obtained by sample cuts prior to grazing.

In 1946, by which time it was clear that peas were greatly superior to subterranean clover as a one-year forage crop and that the barley rotation was yielding similar results to the oats rotation, it was decided to alter some of the rotations. As soil nitrogen appeared to be the controlling factor in the yield of pasture and wheat, oats to which 2 cwt. of sulphate of ammonia was applied were substituted for barley in rotation *C*, thus affording a comparison between applied mineral nitrogen and the biologically-fixed nitrogen in rotation *A*. To enable Wimmera ryegrass and oats to be compared as one-year pastures, peas were substituted for subterranean clover in rotation *B*, to be followed by grazing oats in the pasture phase of the rotation.

The changes have involved some interruption in the continuity of results, as the forage crop is the principal variable and the effects are evident in later courses of the rotations. Tables on pages 41–42 therefore, give the mean yields for the two preceding cycles and the annual yields thereafter of the rotations which have remained unaltered, but where changes have been made only the annual yields from the year in which comparisons became valid are given.

Most noteworthy have been the severe infestations of eelworm on the oats forage crop in three of the past four seasons, resulting in almost total failure of the crop in rotation *D*. However, in the new rotation *C*, the application of 2 cwt. per acre of sulphate of ammonia has offset the effect of eelworm to some extent. The incidence of eelworm on cereals is serious in many parts of the State, and is of sufficient importance to justify investigation.

3. Time and Rate of Seeding of Field Peas.

An investigation relating to time and rate of seeding of field peas was begun in 1944 to determine whether the common practice of sowing peas after the completion of the seeding of other cereals might be a factor in the poor results often obtained by farmers with this crop. The results for 1944–47 which were recorded in the last report confirmed this hypothesis, and the yields in 1948 verified that in most seasons early sowing is desirable. The full results for five seasons are given in Table 3 on pages 43–44.

In three years out of five the yield of grain with early seeding was superior to those with the later sowings, in one year there were no significant differences between times of seeding; and in one year the later sown peas outyielded the early sown.

In four years out of five the heavier seed rates (120 and 150 lb. per acre) outyielded the 60 lb. per acre rate. However, the interaction of time and rate was usually significant, and, with early seeding, in three years out of five either 60 or 90 lb. per acre was superior to the heavier rates.

Generally, the yields of total produce were in similar order to the grain yields, the principal exception being in 1945 when early sown peas produced a higher yield of total produce than later seedings, whereas the differences in yield of grain were not significant.

It would seem, therefore, that early sowing of peas is desirable in South Australian cereal growing districts and this is likely to be more important as average rainfall decreases. If later seedings are made an increased seed rate should be employed.

4. Soil-Water-Plant Relationships under Dry Farming Conditions.

In the cereal growing districts of South Australia, apart from phosphorus which is applied as superphosphate, the two most important factors limiting crop production are soil moisture and available nitrogen. Experiments at the Waite Institute indicate that a rainfall of 16½ inches between May and October inclusive is about the optimum for wheat in this environment, so that over the whole of the wheat belt of the State rainfall is probably sub-optimal.

Numerous soil moisture determinations made in a number of localities at the time of planting of the wheat crop have shown that a bare fallow may conserve up to four inches of rainfall compared with non-fallow soils. This conserved water becomes more valuable to the wheat crop the greater the deficiency between the actual and the optimum seasonal rainfall. A quantitative expression of this relationship has been derived for the *Urrbrae loam*, which is representative of the red-brown earth soils, when cropped on a four-course rotation of fallow-wheat-wheat-pasture.

In this experiment it was possible to compare in any year the yield of wheat after fallow with that of wheat sown on wheat stubble but with adequate supplies of nitrogen added as sulphate of ammonia, thus eliminating as far as possible the effect of nitrogen as a factor affecting the yield in the comparison. The difference in the yields of wheat in the two cases may be assumed to be due principally to the beneficial effects of the fallowing in terms of conservation of moisture and it may be expected that these differences will be greatest when the seasonal rainfalls are low. A statistical examination of the available data shows this to be the case and the results for 16 pairs of observations are expressed in the regression equation:

$$Y=27\cdot9-1\cdot7x \quad (r=-0\cdot69,\ P=0\cdot01.)$$

where Y is the difference in yield between the wheat sown on bare fallow and that sown on stubble with the addition of nitrogenous fertilizer, and x is the seasonal rainfall in inches for the period May to October. When the seasonal rainfall is 16½ inches the beneficial effect of fallowing ceases and with greater rainfalls the effect is reversed.

In addition to the conservation of water the bare fallow also has the effect with soils of relatively low nitrogen status of rendering available as nitrate usually adequate supplies of nitrogen for the wheat crop. There is consequently little or no response to nitrogenous fertilizers with fallow-sown wheat. Stubble-sown wheat does, however, respond to such fertilizers and this response is greater with higher seasonal rainfalls. This effect is represented for 11 pairs of observations by the regression equation:

$$Y=0\cdot30+0\cdot6x \quad (r=0\cdot78,\ P=0\cdot01)$$

where Y is the difference in bushels between stubble-sown wheat manured with 2 cwt. of sulphate of ammonia and not manured, and x is the seasonal rainfall in inches for May to October.

This response of crops to applied nitrogen in terms of seasonal rainfall may presumably be extended to the seasonal responses to nitrogen on stubble soils of varying nitrate content at the time of seeding. This is brought out clearly in an examination of the data from a series of experiments conducted on barley at various centres in which nitrogenous fertilizers were used.

The increase in yield of barley (Y bushels) due to the addition of 1 cwt. of sulphate of ammonia was found to be related to seasonal rainfall and soil nitrate by the regression equation:

$$Y=2\cdot40+0\cdot90\,x-0\cdot58z \quad (R=0\cdot73,\ P<0\cdot01)$$

where x is the seasonal rainfall in inches from May to October, and z is the nitrate content of the soil in parts per million of N to a depth of 18 inches at the time of seeding.

It has been established, both here and particularly at the Rutherglen Research Station in Victoria, that subterranean clover leys are capable of improving the nitrogen status of wheat growing soils to a point where sufficient nitrogen is available to the wheat crop without the need of a long bare-fallow preparation. The widespread adoption of the practice of growing clover or medic leys in rotation with wheat would mean perhaps that the most important function of the bare-fallow would then be the conservation of extra rainfall.

The water relationships of soils and plants under conditions of sub-optimal rainfall offer a fruitful field for further investigation from both the fundamental and applied aspects.

In 1948 a comprehensive field experiment was laid down at the Institute to study in detail over several years the changes in soil moisture to a depth of 5 feet under pasture, fallow, wheat on fallow, and wheat on stubble, and to relate these changes to the use of water by the crops. Soil moisture data are obtained from 288 gypsum blocks buried at different levels in the soil and wired to switchboards for convenience of resistance measurements.

The basic relationship between the electrical resistance of gypsum blocks and the energy status of soil water has been established in the laboratory by the use of a specially adapted pressure membrane apparatus. Different types of gypsum blocks have been examined and it has been shown that certain of these provide an accurate measure of moisture tension in field soils. (See p. 61, Soil Physics.)

A study has also been made of the spot to spot variability of soil water in the *Urrbrae loam*. The great variability in the water content of the clay subsoil was found to be largely accounted for by variation in the percentage clay content. Statistical treatment of the data indicates that soil moisture sampling by the usual gravimetric method requires a very large number of samples to detect changes of 1 per cent. in soil moisture, but that the number of samples may be considerably reduced if a regression of water content on percentage clay is established.

5. Grassland Investigations, South-East.

These investigations which were commenced in 1944 have been continued with assistance from the Wool Research Trust Fund.

(1) *Grassland Survey.*

The ecological survey of the pastures of the Lower South-East has been concluded and the results will shortly be published. The major pasture types have been defined in terms of botanical composition, and the relation of factors of soil, climate and management to their distribution, development and maintenance has been shown. Many of these types are of particular interest because they illustrate the general pattern of development from natural grasslands of low production, to highly productive pastures based on introduced species. The essential features are the changes resulting from the use of mineral fertilizers and the introduction of herbage legumes and, finally, perennial grasses. This is characteristic of the development which has occurred over much of the higher rainfall country of southern Australia.

The legume on which development depends is very frequently *Trifolium subterraneum*. There is, however, a need for alternative legumes on some soils, chief of which are the rendzinas and allied soils. *T. fragiferum*, strawberry clover, is outstanding and will provide the basis for pasture development on these alkaline soils. Its perennial habit and moderate salt-tolerance are additional characteristics of value.

(2) *Field Experiments.*

(*a*) *Investigations of sown pastures on heathlands.*

A series of experiments relating to the failure of sown pastures on heathland soils has been concluded. While a number of fundamental scientific problems remain, the main agronomic difficulties seem to have been resolved. The phosphate level of these soils is very low and at least 2 cwt. per acre per annum of superphosphate should be applied in the early years. Responses have been obtained to copper and zinc and, in wet years, to potash. Even where these deficiencies have been corrected, growth is apparently limited by one or more factors because with time the pasture shows a steady improvement under grazing. This improvement is most marked when pastures, which are several years old, are re-ploughed. Pot tests have shown that the leachate from virgin soil has an inhibitory effect on clover growth. The gradual removal of an inhibiting substance is a possible explanation for the improvement with time which has been observed in the field.

In addition to subterranean clover, strawberry clover has a place on these areas. Its persistence under conditions of water logging during wet winters is a valuable characteristic not shared by the former species.

(*b*) *Investigations of Sown Pastures on the Rendzinas.*

A comprehensive series of investigations has been carried out on the soils of the inter-range flats of the lower South-East, relating to the questions of the most suitable species and strains, and mineral deficiencies. These have further emphasized the value of strawberry clover. The use of improved strains, scarifying the seed to improve germination and a better understanding of the species' requirements have resulted in highly satisfactory stands from recent sowings. The strains Palestine, Shearman's and Clarendon have given the greatest winter and spring yields in plots over a four-year period. With normal grazing, however, the relative performance of more prostrate strains like O'Connor's may be improved.

The effect of applications of copper, zinc and manganese was tested over a wide range of country in a series of experiments laid down in 1948. It has been shown that zinc deficiency is widespread on the rendzinas and associated soils; deficiencies of manganese were also indicated. Further experiments established in 1949 were designed to furnish more detailed information on fertilizer requirements, such as the optimum rate and mode of application of minerals and the frequency of application required. First year results showed zinc responses at most centres and zinc-manganese responses in many cases. These investigations are being continued.

(*c*) *Investigations relating to the establishment and persistence of white clover on the Kalangadoo sand.*

An experiment has been established on the *Kalangadoo sand* relating to possible factors responsible for the failure of *Trifolium repens* to persist on this soil. The low exchangeable calcium status of the soil and micro element deficiency are the factors in question. The total yield of herbage has been increased both by liming and the addition of a mixture of other minerals. White clover has responded to the micro element mixture but the response to lime has not been statistically significant. This experiment will be continued for another year.

(*d*) *Investigation of pasture development on the deep podsolized sands of the ranges carrying Eucalyptus Baxteri.*

The first year results of an exploratory experiment indicate that high phosphate levels (3–4 cwt. superphosphate per acre) are required. Copper applications increased both yields of dry matter and seed production.

6. Top Dressing of Natural Pastures.

A permanent field experiment to determine the effects of equivalent dressings of phosphate (40 lb. P_2O_5 per acre) in the form of superphosphate, basic slag, and rock phosphate and the effect of nitrate of soda added to the basal dressing of superphosphate, on the botanical composition and yield of a natural pasture, has been maintained since 1925. The results in terms of yield and stock-carrying capacity over 25 years are summarized in Table 4 on pages 60 and 61.

The principal results have been discussed in previous reports and the chief value of the experiment now is to record seasonal fluctuations in herbage production, and to provide a source of material for analytical work, for example, soil phosphorus studies.

7. Investigations of Shrub Pastures under Low Rainfall.

The investigations on the management and regeneration of shrub pastures described in earlier reports have been maintained. Seasonal conditions, however, have continued to be unusually favourable and until a succession of dry years is experienced marked changes are not expected.

It has not been found possible to expand the work on the problems of the arid pastoral areas chiefly because of lack of suitable personnel.

8. Weeds and Weed Control.

(1) Cape Tulip (*Homeria collina* and *H. miniata*).

These investigations have been continued with assistance from the Wool Research Trust Fund. An important aspect has been a survey of the total area of infestation in Australia to determine the importance of the problem, to study the autecology of the species and to observe the effectiveness of control programmes. The main conclusions drawn from the survey have been presented in a previous report.

Further evidence has been obtained on the effectiveness of mechanical control methods. Unsatisfactory results can be attributed to poor timing, uneven sprouting, inefficient cultivation methods or failure to follow up previous work.

Following indications of mineral deficiency in soils from several infested areas, field trials were established in 1948 at five Victorian centres. The information obtained from these will assist in the establishment and maintenance of vigorous pastures to reduce re-infestation of areas which have been cleared by cultivation.

A more detailed study has been made of an area, north of Adelaide, which is infested with *H. collina*. This has given further information on factors

which limit the weed's distribution. The type of land use, in particular the frequency of cropping, has a marked influence on the spread of the species. In this area the critical line for the distribution of the weed approximates to that of an annual rainfall of 19 inches. Further examples have been noted of the growth of *H. collina* being limited by soil alkalinity or some associated factor or factors.

Pot and field experiments indicate that control by chemical means can be obtained on non-arable areas. The ethyl ester of D.C.P.A.[1] and sodium M.C.P.A.[2] have given satisfactory results at concentrations of 0·2 per cent. and 0·3 per cent. respectively. The effectiveness of sodium D.C.P.A. was increased relative to that of M.C.P.A. by adding ammonium sulphate to the spraying solution. The application of nitrogenous fertilizer to the soil has also increased the effectiveness of spraying. There is some evidence to show that stomatal behaviour is an important factor; sprays should be applied so that stomates are open during the period that spray droplets are on the leaves. Wetting agents should be used with substances in aqueous solution.

A field survey has shown that figures for percentage dormancy of *H. collina* corms are frequently over 70 per cent.; in such cases the effectiveness of control measures is seriously limited. Corms brought to the laboratory and stored for short periods before planting give sprouting figures approximating 100 per cent. An investigation of factors which may affect dormancy is in progress. One important observation is that good sprouting is obtained on areas which have been burned in the preceding summer.

(2) Onion Weed (*Asphodelus fistulosus*).

Investigations of a preliminary nature, which were conducted in 1949, were designed to provide a basis for further work on the autecology of the species and on methods of control. The effect of environmental factors on germination, the general morphology, seedling development and vegetative reproduction were studied. Growth studies were made on seedling plants in pot cultures, using two soil types and four fertilizer treatments. Similar studies were made in the field with second year plants. Responses to nitrogen and phosphorus were obtained; there are, however, extensive infestations on soils of low fertility.

Of a number of herbicides tested under glasshouse conditions substances of the 2, 4-D type and a number of oils were effective on young plants but in many cases did not prevent re-growth by established plants. Some of the factors investigated were concentration of herbicide, use of wetting agents, growth stage and stomatal behaviour at time of spraying and nutrient status of the soil. Results obtained from these and field tests suggest that the high cost of chemical control methods available at present will limit their use.

A survey of an area at Morphett Vale showed that cultivation is an effective control method. The weed does not appear to be aggressive in the seedling stage and re-infestation of cleared areas has been prevented by establishing phalaris-annual legume pastures.

This work will be continued.

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1 Dichloro-phenoxy acetic acid.

2 Methyl-Chloro-phenoxy acetic acid.

9. Botanical Service.

An advisory service in systematic botany is available to the Departments of Agriculture and of Woods and Forests. The Weeds Adviser of the Department of Agriculture is informed of records of new weeds or new occurrences of weeds previously reported and such advice is reciprocated. During the period 1948–1949 over 1,100 plant specimens were determined and reported on. Included in this number were numerous collections of specimens from members of the staffs of the Commonwealth Department of Works and Housing, Department of Lands, Department of Mines, Animal Industry Division of Northern Territory Administration and C.S.I.R.O. Division of Soils as well as from Departments of Agriculture and Woods and Forests and members of the Waite Institute staff.

The noxious weeds most frequently brought to our notice were weld (*Reseda luteola*), hoary cress (*Lepidium Draba*), caltrop (*Tribulus terrestris*), and the broad-leaved cotton-bush (*Asclepias rotundifolia*). Other weeds worthy of mention which were the cause of many enquiries were nutgrass (*Cyperus rotundus*), innocent weed (*Cenchrus tribuloides*) and bladder campion (*Silene Cucubalus*). Following the press publicity given skeleton weed (*Chondrilla juncea*) as it was discovered in increasingly large areas on the eastern side of the River Murray and also after it was reported to have crossed the Murray at Caloote, numerous suspected plants were sent in from all parts of the State. Fortunately many proved to be comparatively harmless though closely related plants.

All enquiries for advice on weed control are handled by the Weeds Adviser, Department of Agriculture.

Alkali mallow or white weed (*Sida hederacea*), a native of sub-saline soils in the valleys of California and other parts of the U.S.A., was recorded from Australia for the first time in March, 1948, when it was found as a garden escape at Kadina. As this potentially troublesome weed succumbs to the hormone type weedicides it has not occasioned alarm. Two crucifers, *Lepidium latifolium* and *Brassica elongata,* new introductions to Australia, have appeared as localized infestations, the former at Semaphore and the latter at Murray Bridge. Both are natives of Europe and Western Asia. Cluster winter-cherry (*Withania somnifera*), a native of the Canary Islands, was recorded for the first time in Australia when it was discovered at the Duckponds near Port Lincoln. Apparently this plant had been established in the area for some years but as it had not become aggressive in that time it is not considered to be a potential nuisance.

Cobblers' peg (*Bidens pilosa*), known for some years as a weed in New South Wales, has become established in a suburban street but is not known to have spread further. A number of plant species have been recorded from new localities in this State, both weeds spreading to wider fields and native plants being noted for the first time in new localities.

Genetics and Plant Breeding

1. Wheat.

At the conclusion of the 1948 season eight new rust resistant varieties were registered and released through the Department of Agriculture and Roseworthy Agricultural College who have undertaken the responsibility for their distribution to the farmers of South Australia. The varieties, each deriving resistance from Gabo, are: Bencubbin 48, Dirk 48, Dundee 48, Javelin 48, Rapier 48, Ridley 48, Scimitar 48, and Seewari 48. One derivative Ranee 48, although rust resistant, has the same poor baking quality as the original Ranee, and on the recommendation of the Wheat Improvement Committee it was deemed inadvisable to release this strain for general cultivation.

An additional rust-resistant strain of Insignia, Insignia 49, was made available for bulk sowings in 1950.

The appearance of a new biotype of *Puccinia graminis tritici* in Queensland and New South Wales stresses the need for sustained attention to breeding for resistance to stem rust. Accordingly, new sources of resistance are being investigated and special attention is being given to crossbred material possessing the type of resistance associated with the variety Hope.

The programme for incorporating resistance to Australian races of *Tilletia caries, T. foetida* and *Puccinia triticina* has been carried through a further stage.

Yield trials have been continued at the Waite Institute, Saddleworth and Pallamana, the results of which are tabulated on pages 62–65. With the co-operation of the State Department of Chemistry all crossbreds are thoroughly tested for their baking quality characteristics before being released to farmers. Five varieties, Warigo, Dirk 48, Javelin 48, Ridley 48 and Scimitar 48 have proved highly satisfactory from this point of view.

The results of investigations on the genetics of resistance of wheat to various physiological races of *Tilletia caries* and *T. foetida* have been submitted for publication. These studies, commenced in 1941, are being continued concurrently with the breeding programme. Evidence is accumulating which indicates the superiority of the Doubbi gene over others in controlling stinking smut of wheat in this country.

2. Peas.

Yield trials have been continued during the years under review, the results of which are tabulated on page 66. Two early maturing varieties Alaska and Collegian × Maori King have been made available to farmers for trials in the cereal districts of the State.

3. Fibre Flax.

Rust-resistant varieties and dual purpose crossbreds returned high straw yields in trials at the Waite Institute. The problem of lodging is becoming of increasing importance, and it is gratifying to note that several crossbreds have proved superior to standard varieties in this regard. One rust-resistant crossbred (Saginaw × Ottawa) × Norfolk Earl × Norfolk Earl has shown sufficient promise to warrant its further trial on large scale plantings.

4. Oil Crops.

Work on the breeding of oil crops has been consolidated and now embraces studies with linseed, safflower and *Brassica* spp. Comparative tests in 1949 demonstrated the superiority of rape and safflower over linseed with respect to both seed yield and oil production per acre.

Linseed. The establishment of this new crop in South Australia has emphasized the need for breeding varieties adapted to local conditions. Although, in the first instance, rust (*Melampsora lini*) was the most serious disease problem holding back the development of the industry, good resistant varieties are now available. However, in each of the past two years wet periods of weather during the spring months have favoured the development of Pasmo (*Sphaerella linorum*) and in certain instances seed losses have approximated 50 per cent. Two introductions from the United States—Sheyenne and Crystal—exhibited a sufficiently high resistance as to warrant their use as parents in a breeding programme.

A detailed analysis of the genetic factors in *Linum usitatissimum* for resistance to Australian races of *Melampsora lini* has been commenced.

Safflower. Co-operative work with the Defence Research Laboratories, Melbourne, has been continued. Seed yields of the order of 1,500 lb./acre were secured in both the 1948 and 1949 seasons. Detailed figures of varietal trials are tabulated on page 67.

In former years the standard variety has been Niphad 630, but this has now been replaced by Selection 47–53—a strain which yielded seed with an oil content of 38 per cent. in each of the seasons under review. Seed stocks of Selection 47–53 have been increased for further trials in country districts.

5. Tomatoes.

Tomato Spotted Wilt, the most serious disease of tomatoes in South Australia, has always proved the most difficult to control. In 1948 an Argentine variety Rey de los Tempranos was introduced from the United States and subsequently shown to possess resistance to the tomato spotted wilt virus under local conditions.

Confirmatory evidence of its resistance was secured in 1949. Crosses have been made with a view to incorporating its resistance in local varieties.

6. Pasture Plants.

Cytological studies, necessary as a background to the understanding of genetical and breeding problems, have been commenced. Attention, in the first instance, is being given to Australian native grasses.

Agricultural Chemistry

1. Improvements in Laboratory Technique.

An interest has been maintained in the development of new and improved methods for the examination of soils. Reduction of iron oxides by magnesium in buffer solutions of controlled pH was investigated and a suitable procedure was developed for the quantitative determination of free iron oxides in soils. Reduction was brought about more rapidly, and under less drastic conditions, than in methods previously in use. The xylenol method for the determination of nitrates was examined. The method offers many advantages in the determination of small amounts of nitrates in soil studies, and a technique is being worked out for the determination of nitrates and ammonia in the same soil extract.

2. Soil Fertility Studies.

(1) *Phosphorus in South Australian Soils.*

In continuation of the earlier studies on the fractionation and availability of phosphates in soils a long term field experiment has been laid down at the Waite Institute. This experiment has been designed to gain more precise information on the residual value of superphosphate applied with previous crops and to correlate responses to superphosphate with the phosphate status of the soil as determined by chemical analysis. As was indicated in the last report sometimes as little as 10–25 per cent. of the superphosphate applied with a crop is absorbed by that crop; the residue remains in the soil and has a cumulative effect in building up soil fertility. Fertility may be built up after a number of years to such an extent that cereals no longer respond to current applications of superphosphate.

On the site chosen for the present experiment, the phosphate status of the soil had already been built up to such a point. Cropping will be continued, in a fallow-wheat-barley rotation with controlled applications of superphosphate, to determine the number of crops that can be removed before a response to super is again shown. By means of crop and soil samples, changes in the phosphate balance sheet are being followed. The first two crops have been particularly heavy and it is apparent that the reserves of soil phosphate are being steadily depleted. The rate of removal of nitrogen in this rotation is also being studied.

(2) *Soil Investigations on Kangaroo Island.*

Investigations into the fertility of soils of the *Seddon* series of Kangaroo Island have been commenced but progress was temporarily retarded owing to loss of staff. The project, now being actively pursued, is intended to supplement the soil surveys that have been carried out by the C.S.I.R.O. Division of Soils and to build up more information about the soils of the area by studying their chemistry in greater detail. These soils are notoriously deficient in nitro-

gen and phosphorus; they also show a response to copper. Even when these deficiencies have been overcome the growth of some plants, notably grasses, is unsatisfactory and the reason for this is being sought. A preliminary pot experiment has defined the nature of the problem and indicated features requiring more detailed study. Investigations have also disclosed that these soils possess an extremely low nitrifying power in their original state and attention is being devoted to possible factors controlling this.

(3) *Micro-Elements.*

Apart from the deficiencies of some of the biologically important micro-elements in regard to the Kangaroo Island project, work on this subject has been restricted to a study of the amounts of copper and molybdenum in subterranean clover at different stages of growth. Plant samples were collected at regular intervals throughout the growing season. The proportion of copper in the dry matter increased at first but fell somewhat during the period of flush spring growth. Molybdenum in the dry matter decreased progressively throughout the growing season.

(4) *Nitrification Studies.*

Soil samples from Rotation Experiment C53 have been examined for their rate of nitrification when incubated under favourable conditions. Surface soils from the four course rotations showed a marked accumulation of readily nitrifiable compounds compared to the bare fallow-wheat rotation. After incubation for 60 days soil from the bare fallow-wheat-grazing oats-pasture rotation showed a production of nitrate nearly twice as great as that of the bare fallow-wheat rotation. Accumulation in the soil of nitrogen and organic matter is also being examined in other rotation experiments.

3. Miscellaneous.

A number of soil samples have been examined for other departments in connection with work in progress by them. These have included soil samples from a vegetation survey in the South-East, a large series of soils collected from an area in the Adelaide Hills infested by crickets, and a series of samples selected to evaluate the tolerance of strawberry clover to soil salinity at Avenue Range. Results from the latter investigation showed that growth was good and little or no damage due to salt was shown by plants growing on soils containing up to 0·25–0·30 per cent. of total soluble salts. With increasing amounts of salts the severity of salt damage increased.

Post-graduate research projects in progress include a study of the electrodialysis of soils and the characterization of the soils collected during the soil survey of the Barossa district by the Division of Soils of the C.S.I.R.O.

Plant Physiology

The main work of the department was associated with studies of growth-promoting and -regulating substances in plants.

Whilst the prototype chamber for the culture of test plants, referred to in an earlier report, was still in use for the greater part of the period covered by the present report, considerable progress was made in the construction of a more permanent unit.

In view of the continued importance of the assay of hormones by the *Avena* technique, some attention has been paid to conditions under which it is carried out, with particular reference to the test plants. The following factors were studied:

Size of grain. Indications are that plants arising from smaller caryopses are slightly more sensitive than those from larger caryopses. The plants from the smaller grains are smaller and more irregular in germination and subsequent growth, whilst the plants from larger grains are considerably more difficult to manipulate in the test. In practice, it would appear desirable to discard both the very large and the very small grains. Some evidence has been found that the differential sensitivity is associated with differing growth rates of plants arising from the two size classes of grain, though further work is required to establish this with certainty.

Source of seed. The variety conventionally used in such work is Victory (Siegeshafer or Segrehafer). Undoubtedly most seed has its ultimate origin in the Sveriges Utsädesförening, Svalöf, Sweden, yet it is clear from the literature that, in the course of propagation elsewhere, seed differing in sensitivity from the parent stock has arisen. Several generations of Victory oats have been grown under pure line conditions at the Waite Institute to establish whether these changes are attributable to environment or alteration in genetic make up. This material is being analysed at present.

Deseeding. A well known modification of Went's original technique, consisting of removal of the endosperm (deseeding) at an early stage to give plants of greater sensitivity, has not proved successful in this laboratory, largely because the operation so reduces the growth of the enclosed first leaf as to render the plants unsuitable for the required manipulations.

This observation lead to a study of factors controlling first leaf development. Supplying such deseeded plants via the roots with macro-nutrilites as carbohydrates and amino-acids, and with the micro-nutrilite indole acetic acid did not enhance the depressed first leaf growth. Moreover, removal of the coleoptile at an early stage, with intact endosperm, resulted in a depression of first leaf growth similar in magnitude to that produced by deseeding. Although no fractionation of biochemical entities has yet been attempted, these results are consistent with the hypothesis that some substance in the seed reserves is metabolized in the coleoptile. The resulting metabolite is passed to the first leaf where it exercises a favourable effect on its growth.

Entomology

The activities of the Department of Entomology are divided between research, teaching and the maintenance of the State Advisory Service in entomology. Enquiries on entomological matters relating to agriculture, horticulture, forestry, livestock, public health, stored products and to household problems, are being received in increasing numbers; many technical enquiries concerning the modern insecticides and their effects were also dealt with.

Among particular activities the preparation of a text-book on insect ecology is being undertaken in collaboration with a worker in the University of Sydney.

1. Insect Pests of Permanent Pastures.

The research work of the Department during 1948–49 was directed chiefly to problems resulting from insect activity in pastures in the higher rainfall areas of the State. It is well known that under conditions of grassland management that entail continuous grazing over a number of successive years, the insect inhabitants of such an environment may increase considerably; this is particularly the case with subterranean forms, or to those which are closely associated with the soil surface. There has been a great expansion in the acreage of permanent pasture in South Australia in the past five years, a post-war development that is still in progress. Much land previously subjected to intermittent cultivation and cropping is now being converted to permanent pasture. On land of this kind a variety of insect problems has assumed a new importance.

It is of interest that, whereas many pest insects of Australian agriculture are imported species, the pasture-infesting forms with which we are here concerned are almost all native insects. Under the methods of grazing and land-management that were in use until the practice of top-dressing with artificial fertilizers became general about twenty years ago, these insects seldom, if ever, came under notice as pasture pests. Native grasses formed the principal pasture constituents; these rarely formed a closed sward, due to the relatively low natural fertility of the soils concerned. The associated herbage-feeding insects remained at a well-adjusted equilibrium with this environment, in which quantity of food available to them, its continuity of supply, and shelter from desiccation, fluctuated widely.

In recent years outbreaks of one or other of these insects have been reported, and pasture damage has at times been severe. A programme of investigations relating to the problem in South Australia was therefore commenced in 1948; it is proposed to extend the work to cover the chief insect pests as staff becomes available.

The black field cricket *Gryllulus commodus* Walker* was first examined. This insect swarms in particular years, and may cause severe damage to pastures on heavy clay soils. The adults and nymphs eat the plants off at the soil surface, and in many cases kill them. The pasture may then be invaded

* Usually known in Australia as *G. servillei Sauss.* The above name is used on the authority of Dr. L. Chopard of the Paris Museum.

by weeds, and it may require a year or more, after re-seeding, to restore its carrying capacity.

A comprehensive survey of this insect is now in progress. It shows that there is one brood a year, the adults being present in late summer or early autumn (February to April), when eggs are laid in the soil. These remain dormant through the winter and until early in the following summer, when they hatch. The young nymphs feed through the summer and reach maturity in February and March.

Although *Gryllulus commodus* is widely present in the wetter parts of the State, it reaches plague numbers only on heavy clay soils, which remain moist longer into the spring and dry out to form deep cracks in summer. The reason for this association is found to reside in the moisture requirements of cricket eggs. These possess no mechanism which enables them to resist desiccation; they survive in the soil only when it is continuously wet. Clay soils, particularly those subject to swampy conditions, provide the required moisture conditions for cricket eggs in years of favourable rainfall, and in such years cricket swarms may be produced. In dry winters mortality among cricket eggs may be extremely heavy, and in such a year cricket numbers may fall away markedly. The deep cracks developed in summer have some significance in the survival of the adult insects; on open pastures these provide shelter from birds and other predators, and give protection from desiccation.

The distribution of cricket plague areas in the State has been mapped, and studies on control have been commenced. Control is rendered difficult by the large tracts of land that may require treatment, and by the difficulty in assessing the results of treatment due to the behaviour of the insects in inhabiting soil cracks.

During the period under review an unusually severe outbreak of the pasture-feeding caterpillar *Oncopera fasciculata* Walker occurred in the south-eastern part of the State. The opportunity was taken to make observations upon this insect in the field; these are being continued as part of the general programme of investigations on pasture insects already mentioned.

O. fasciculata is one of several species of hepialid caterpillars that cause damage to pastures in eastern Australia, where they are known as underground grass grubs. They are particularly destructive in Tasmania, but also occur in Victoria and on the volcanic soils of the Atherton plateau in north Queensland. Their presence in south-eastern South Australia is the most westerly extension of the known range of this group of insects. All species require relatively cool moist conditions, with sufficient summer rain to permit some growth of perennials at this time. The only part of South Australia that provides conditions of climate and soil suited to *Oncopera* is found in the South-East (County Grey), within a radius of about thirty miles of Mt. Gambier.

Oncopera fasciculata is a native insect. Its range extends from South Australia eastwards across southern Victoria to Gippsland. Although it has come under notice for many years as a limited pest of pastures in the South-East, it is only in comparatively recent years that it has caused widespread damage. It was first recognized on a field scale in 1935, again in 1937–38, after which it attracted no attention until 1948–49, when outbreaks of unusual severity occurred widely in the South-East.

The caterpillar stage of this insect lives in a vertical burrow in the soil. This is partially lined with silk, and opens at the soil surface by a fan-shaped entrance concealed by fragments of plant debris. The insects emerge at night to feed on the tops of pasture plants, which are cut off at ground level; in tall pasture the plants are not eaten completely, but are felled and remain as a prostrate cover to the soil surface. Every plant in the sward may be cut off in this way, and re-growth is prevented by continued feeding. A heavy fall of rain which washes away the loose grass may show the extent of the damage, when bare patches of soil, varying in size from a few yards to many acres, are revealed.

Oncopera fasciculata has one generation each year. The adult moths emerge from the pupae in the soil in September and October, and after a remarkable mating flight, eggs are laid at once. The eggs hatch on the soil surface in the presence of adequate moisture, during the October-November period, and depending on the amount of rain at that time, they survive and establish themselves in the pasture in short burrows in the soil surface. The young caterpillars continue to feed and grow, and if numerous, their presence can be recognized in a pasture in late summer. By March the soil surface may be denuded completely, except for a layer of plant litter produced by the caterpillars. Feeding continues actively after the autumn rains, and where grubs are strongly established no pasture growth is permitted. Larval numbers are then of the order of 10 to 30 per square foot, the burrows are about four inches deep. By May the caterpillars are full grown, and are two inches long. Feeding is completed in mid-winter when the larvae enter the pre-pupal condition and become whitish in colour. The pupae appear during July and August and these remain in the larval tunnels until the moths emerge in September-October. It will be seen that although severe pasture damage is usually not apparent until March, or until the early rains have washed patches bare, an inspection of such a pasture would enable the recognition of infestation from December onwards. The silken webbing of burrows, and the young larvae as revealed by digging, would provide an early indication.

There is much evidence that the period of hatching of the eggs in October-November is a critical one for the survival of this insect. Both the developing eggs and young larvae require continuous moisture to survive; this is usually assured among dense or rank pasture, and it is common experience that pasture cut for meadow hay in summer may be heavily attacked in the subsequent autumn. The distribution of rainfall during the early summer months appears to be of critical importance and in dry years the mortality of young larvae must be very heavy. The individual moths lay 1,000–1,500 eggs each, and may fly in enormous numbers. It is clear that in many years there are few survivors due to unfavourable weather conditions; in the occasional year, when conditions particularly in the early summer, are favourable, a major outbreak may result.

Much additional detailed information on the ecological relationships of *Oncopera* has been obtained.

The problem of economic control of an insect that may be present in plague proportions over many square miles of pastures, is one that is not easily solved. It is probable that various insecticides could be used, but the cost of such materials per acre is high. As a rule pasture infestation is patchy

rather than uniform, and aerial application over entire pastures would prove unduly costly. Cultivation is not a satisfactory protection, since the grazing value of a pasture is lost in the process. The approach to the control of this insect is believed to lie through suitable land and pasture management. It is known that well-grazed pastures in spring provide little shelter for the newly-hatching caterpillars; there is some evidence that mowing in early summer may produce similarly unfavourable conditions for the young larvae. The view is widely held by farmers that the trend from rotational cultivation and cropping, which was the usual practice a quarter of a century ago, to a widespread system of "permanent" pastures has in itself contributed to the present status of *Oncopera* as a major pasture pest.

2. Introduced Insect Pests.

South Australia is separated geographically from the agricultural areas of other States by barriers provided to some extent by distance, but principally by the arid nature of the intervening territories. As a result the movement of insects into this State from its neighbours is hampered; this is particularly the case with plant pests, which lack a continuous sequence of food plants to allow them to bridge the natural barriers.

Many serious insect pests are established in various parts of the Australian continent that have remained relatively localized. Some of them which do not occur in South Australia would be capable of thriving in our agricultural and horticultural areas, and constant vigilance is maintained by agricultural and quarantine authorities to exclude them. The great development of interstate air and road transport in recent years makes this last more difficult.

In 1947 the first occurrence of the Queensland fruit fly *Strumeta tryoni* Froggatt was recognized in an Adelaide suburb, and a full-scale eradication campaign was instituted by the South Australian Department of Agriculture. Reference has already been made to this campaign in the previous report. In the summer of 1948 the disagreeable discovery was made that a second fruit fly, the dreaded Mediterranean species *Ceratitis capitaa* Wied., was also established in some gardens in an Adelaide suburb. The eradication campaign was extended to include this occurrence; its location indicated that its introduction had occurred independently of the case of the Queensland fruit fly. During the summer of 1948 no trace of *Strumeta* was located. In the summer of 1949 this insect was found in two isolated points in the suburbs, while *Ceratitis* was found over a wide area elsewhere in the suburbs. The eradication campaign was again extended to these areas. So far no evidence has been found of any extension of the occurrences to any commercial fruit-growing area. The campaign is being maintained; it faces great practical difficulties in dealing with densely inhabited suburban areas, in which every home garden contains many kinds of fruits that serve as hosts for these insects. The Department of Entomology has continued to provide technical assistance and guidance to the Department of Agriculture on the entomological aspects of this campaign.

Other insects to be recognized for the first time during the period under review were the dynastid beetle *Heteronychus sanctae-helenae* Blanchard. This African beetle has been established for some twenty years in New South Wales and more recently around Perth, Western Australia. Specimens from a garden

in the Adelaide suburb of Hindmarsh were recognized as this species in April, 1948, and a survey by the Department of Agriculture showed it also to occur at several seaside suburbs. This insect is most active and troublesome under summer rainfall conditions; in the Mediterranean climate of Adelaide (as at Perth) it is restricted to watered turf, in which it may be a pest. It seems likely however, that it will be a pest of limited importance under local conditions.

The currant borer moth *Aegeria tipuliformis* Clerck was reared from this host from Mt. Lofty. It has been established for many years in Tasmania, and more recently in Victoria and New South Wales. It is chiefly a pest of black currants, which are little grown in the Adelaide hills; there is evidence that this insect has been known to growers for a number of years.

Reference was also made in a previous report to the curious case of the North American bark-beetle *Ips grandicollis* Eich., which was found to be established in an isolated pine plantation at Wirrabara State Forest, and where it has more recently been found to kill healthy *Pinus radiata* trees. There appears to be no record of this insect as naturalized anywhere else outside the North American mainland, and the means whereby it reached Wirrabara is a mystery.

In April, 1948, a cabinet maker reported that unusual insects were emerging from a flitch of Baltic pine derived from a recently imported shipment. The beam was found to contain many living adults of the wood-boring wasp *Sirex juvencus* L.; numbers had already emerged. The related *S. noctilio* F. has become established in New Zealand, and is regarded as a serious pest of softwood plantations in that country. The South Australian pine plantations remain largely free from northern hemisphere insect pests of conifers, though three species of bark beetle are already established.

The European domestic cricket *Gryllulus domesticus* L. was found some years ago to be strongly established in several rubbish dumps in brick-pits in an Adelaide suburb. This insect was behaving as a pest in houses in the vicinity; it is the first record of its occurrence in Australia.

The foregoing account shows that there is a steady movement about the world of pest insects, some of which may be grave threats to particular primary industries; this movement is being aided by the speed and variety of modern transport. It is worth drawing attention to several pests, some of which are already established on the Australian continent, and which could be expected to flourish under local conditions.

The Argentine ant, *Iridomyrmex humilis* Mayr., has been established for some twenty years in Melbourne. More recently it reached Perth and Albany in Western Australia, where it is causing severe inconvenience as a house pest and is the subject of costly control campaigns. It has also been reported in 1950 from Sydney. It is transported as small entire colonies in the soil of potted plants, and in the wrappings of articles in transit.

The European earwig, *Forficula auricularia* L. is a troublesome garden pest, which has been present in Tasmania for many years, and has appeared more recently in the Blue Mountains and at Ballarat, Victoria. It could thrive in the Mt. Lofty ranges. Two truckloads of potatoes from Victoria recently intercepted at Adelaide contained many live specimens of this earwig.

The pea weevil, *Bruchus pisorum* L. is established in pea-growing areas in Western Australia. It is a serious pest of peas, particularly when grown for the split pea industry, or for canning. It is readily transported in seed peas, inside which the insects are concealed.

Other species that should be listed are the European red mite of fruit trees (*Paratetranychus pilosus* C. and F.) which is now restricted to Tasmania; the San Jose scale of fruit trees (*Quadraspidiotus perniciosus* Comstock) which is established in Eastern Australia but appears to be absent from this State; the mosquito *Aedes aegypti* L. which is present in Western Australia and New South Wales; and which is a troblesome house pest and a vector of dengue fever. There are many others; the list is however, long enough to indicate the nature of the risks of introduction of further undesirable insects and mites.

Plant Pathology

The combination of two circumstances, an increase in the size of staff of the Department of Agriculture and the occurrence of weather favourable to the greater development of plant disease, increased the demand on the advisory service which this department provides. The years 1948 and 1949 were both characterized by more late spring and early summer rain than usual. As a result glume blotch in wheat (*Alternaria* spp.), Coryneum blight in peaches (*C. beijerinckii*), downy mildew in vines (*Plasmopara viticola*) and black spot in apples (*Venturia inaequalis*), to mention a few examples, developed to a degree which has seldom if ever been observed previously in South Australia. By 1949 Downy mildew had spread to practically all parts of the State where vines are grown but, fortunately, has not caused any great damage to what is one of the States major primary industries. The widespread occurrence of the disease has, however, impelled prudent growers to adopt and incur the expense of protective spray measures.

Three new diseases, not previously recorded came to notice during the period under review. Basal glume blotch (*Pseudomonas atrofaciens*) was identified on Sword wheat but may well prove to be of little economic importance. Ring spot of lettuce (*Marssonina pannattoniana*), a seed borne disease was found in an early season variety named 615. This disease can be destructive to winter grown lettuces. Leaf spot (*Cylindrosporium hiemalis*) was found in a nursery bed of cherries the stocks of which had been imported from Europe. The nursery area was remote from the main cherry growing districts and the Department of Agriculture took thorough measures to eradicate the disease.

(1) *"Takeall" disease of wheat.*

Work on this problem has been continued with experiments in the field and with pots in the glasshouse. The general character of the programme was reviewed at some length in the last report and it is only necessary to refer briefly to two lines along which the work has been taken.

A field experiment was carried out to ascertain what effect different rotation systems had on the survival of the disease. Naturally contaminated land

at the Waite Institute was used and portions were ploughed at such times in 1948–1949 that the period of fallowing prior to seeding in 1949 varied. In addition to these plots with differing fallow periods, there were others where crops of oats, for hay and for grazing, peas and barley were grown as a preliminary to wheat seeded either early or late in 1949. Three varieties of wheat were used and due attention was given to replication and methods of sampling which need not be detailed here.

It was found that a normal fallow period, where the land was first ploughed up to as late as 2nd July effectively reduced though it did not completely eliminate the disease. Shorter fallow periods consequent on later ploughing were less effective. The use of oats for grazing gave results similar to those for bare fallow but oats for hay was only partially effective. Field peas allowed to mature their grain were significantly more efficient than oats for hay but again less efficient than oats that had been grazed. It is suspected that the lowered efficiency of the non-susceptible crop plants, oats and peas, was, in the circumstances of this experiment due to the survival of susceptible grasses (e.g. *Bromus* spp.) which grew and matured as volunteers in these crops.

In the glasshouse and laboratory a special effort to understand the pathology of the takeall has been made. In the field this disease may kill young plants as seedlings or plants may survive to wilt and die any time after the heads emerge, a form of the disease which is often given a distinctive name such as whiteheads or haydie. It is quite easy to reproduce the seedling phase of the disease in pot culture but much more difficult to induce the symptoms of whiteheads. The induction depends in part on factors which influence the activity of *Ophiobolus graminis* over the considerable stretch of time that the plant is growing and in part on factors which influence the growth of the wheat plants, especially its roots. Experience indicates that it is practically impossible to co-ordinate these groups of factors in such a way that the progress of the disease in pots exactly parallels that which occurs in the field. However, this difficulty, once it is realized, is not in itself very important but it is very important in interpreting the experimental study of claims that this or that soil treatment has a significant effect on the progress and development of takeall. As a consequence of a study on the growth of healthy and inoculated plants and their water relationships we are now in a good position to interpret a large body of evidence gleaned from experimental studies in pot culture.

(2) *Dieback or Gummosis of Apricots.*

Unfortunately the field work on this disease described briefly in the last report was interrupted by the resignation in the middle of 1948 of the Research Officer appointed by the Commonwealth Scientific and Industrial Research Organization to assist in this work. In the meantime a great deal of work has been done in efforts to elucidate the life history of the fungus concerned in this disease. There is abundant evidence for the pathogenicity of the fungus *Cytosporina* which is always readily isolated from active lesions on branches. But the distribution of the disease in the field and other features suggest that the fungus produces a perfect stage the nature of which is not yet known. Efforts to induce *Cytosporina* to produce a perfect stage have been unavail-

ing. From the other angle a species of *Cryptovalsa* has been studied intensively and among the very numerous strains isolated there were some which in many ways resemble the *Cytosporina* isolated from gummosis lesions. However, all the strains tested have proved to be virtually non-pathogenic for apricots and hence differ in an important respect. The officer concerned in this work has been awarded a scholarship from the United States which will enable his studying the problem of fungal genetics more deeply.

(3) *Bacterial blight of cherries.*

Intensive field work here has also had to be suspended for lack of staff but an occasional inspection of cherries has led to the belief that while bacterial blight is undoubtedly of importance it is by no means the only factor responsible for the decline of cherries in this State. With increased staff it should now be possible to investigate these other factors, especially the importance of virus disease for whose presence there is considerable field evidence.

In the last report reference was made to difficulty of distinguishing the various species of *Pseudomonas* pathogenic for plants and the need for better differential criteria. The question has been studied with *Pseudomonas* isolated from many plants in Australia, and with cultures received from other parts of Australia and from abroad. In addition to examining the usual criteria, sugar fermentation, pathogenicity for different hosts, etc., attention has been given to lysis by bacteriophages isolated from various sources.

Climatology

The interest in climatology which has been a characteristic feature of the work of the Waite Institute since its foundation has been maintained. Opportunity has been taken to collect and revise for South Australia all available rainfall data to 1943, together with the means for temperature, relative humidity and saturation deficit at selected stations. These data have been brought together in tabular form giving mean monthly rainfall and evaporation and the percentage of seasons with rainfall effective in any given month. The mean length of the rainfall season and the percentage frequency of drought years is also given for 204 stations in the State (Reprint 524).

The influence of temperature on the growth rate of perennial pastures under irrigation was determined from records of the growth of irrigated pastures at Woods Point. Additional data from Queensland records was also included. It was found that between temperatures of 46° F. and 80° F. the yield of pastures, as cut at monthly intervals, followed the Van't Hoff rule with respect to response to temperature. For each 18° F. rise in temperature a 2·3 to 3·7 fold increase in yield was found provided that soil moisture conditions remained favourable.

The climatic index P/E^m connecting precipitation and evaporation to which reference was made in the report for 1943–1947 has been further tested. This ratio with m having a mean value of 0·73 was found to be a satisfactory index for the leaching factor in soil formation, based on an examination of the

records of drainage gauges and the measured losses of water from field crops and native vegetation, when referred to evaporation from a free water surface.

For a variety of reasons the value of m has been chosen as 0·75 in order to avoid too great an element of unjustifiable precision.

Atmospheric saturation deficit has frequently been used as an index of this evaporation in our work and it has been found that for practical purposes the ratio $P/E \cdot ^{75}$ is almost one-tenth of the corresponding ratio $P/sd \cdot ^{75}$ when both P and E are expressed on a monthly basis.

It has been found that appropriate critical values of the new index for rainfall effectiveness are as follows:

Monthly values of the climatic index of rainfall efficiency for different levels of soil moisture and vegetation needs.

	$P/sd.^{75}$	$P/E.^{75}$
For the break of season	4	0·4
For vegetation of low transpiration or for the start of drainage through bare soil	8	0·8
For vegetation of average transpiration and catchment areas	12	1·2
For high transpiration	16	1·6
For rice fields	20	2·0

It has been found that the so-called potential evapo-transpiration of Thornthwaite* is very close to the estimate for vegetation of low transpiration.

Using the index $P/sd \cdot ^{75}$ it has been possible to revise the map illustrating the length of the growing season in Australia which was drawn up by the Rural Reconstruction Commission in 1943 on the basis of work from the Waite Institute from 1936 to 1939. The new map makes use of the concept that a period during which the index $P/sd \cdot ^{75}$ exceeds a value of 4 must include a substantial proportion of time during which the value 8 is equalled or exceeded.

The wave form analysis of the annual march of temperature designed to reduce the 12 monthly values to the three characteristics, mean, amplitude and phase has been extended to include most of the available temperature data throughout the world. World maps showing the lag of air temperatures and of sea surface temperatures behind solar radiation are in course of preparation.

These methods of characterization of temperature and of rainfall efficiencies are being applied to a comparative study of the climates of Australia and Argentina. This type of comparative climatology is of great importance to Australia in connection with the search for plants, native to other continents, of likely economic importance to Australia.

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*"An Approach toward a Rational Classification of Climate". C. W. Thornthwaite: The Geographical Review, Volume XXXVIII, 1948, Pages 55-94.

Meteorological Records

Meteorological observations in connection with the work of the Waite Institute are being made at three centres: at the Waite Institute itself, at Pallamana in the Murray Mallee (north-west of Murray Bridge), and at Yudnapinna (north-west of Port Augusta). The records for the years 1948 and 1949 are given in the following tables:

Monthly rainfall and evaporation in inches for 1948 and 1949, Waite Institute.

Month	Rainfall.		Evaporation.	
	1948.	1949.	1948.	1949.
January	0·08	0·24	8·41	8·13
February	0·23	2·70	7·67	5·32
March	0·21	0·12	6·64	6·09
April	4·70	0·27	3·31	4·11
May	3·15	2·38	2·08	2·29
June	2·91	1·46	1·52	1·58
July	1·97	2·81	1·81	1·70
August	3·63	1·65	2·57	2·73
September	0·65	1·42	3·60	3·44
October	5·32	6·06	4·26	4·10
November	1·50	2·59	5·57	4·42
December	1·26	0·20	7·24	7·01
Total	25·61	21·90	54·68	50·92

Mean monthly air temperatures for 1948 and 1949, Waite Institute.

Month	Maximum		Minimum		Mean	
	1948	1949	1948	1949	1948	1949
	°F.	°F.	°F.	°F.	°F.	°F.
January	82·7	80·5	59·0	59·2	70·8	69·8
February	82·1	73·5	61·0	56·9	71·5	65·2
March	75·0	76·3	56·4	56·8	65·7	66·5
April	69·6	71·0	53·5	52·8	61·5	61·9
May	62·0	62·4	49·8	49·1	55·9	55·7
June	58·2	57·5	45·4	43·9	51·8	50·7
July	56·5	58·0	44·3	46·1	50·4	52·0
August	61·7	61·4	47·7	47·8	54·7	54·6
September	66·7	64·8	49·1	47·7	57·9	56·2
October	66·0	66·8	49·4	51·9	57·7	59·3
November	72·4	69·4	52·6	53·8	62·5	61·6
December	78·7	78·1	56·7	56·0	67·7	67·0
Mean	69·3	68·3	52·1	51·8	60·7	60·0

Mean monthly soil temperatures at 1 inch, 6 inches, 12 inches and 24 inches for 25 years, 1925-1949, Waite Institute.

	At 1"		At 6"		At 12"*		At 24"*	
Month	Max. °F.	Min. °F.	Max. °F.	Min. °F.	Max. °F.	Min. °F.	Max. °F.	Min. °F.
January	109·6	63·8	85·5	71·3	78·1	72·9	73·7	71·5
February	106·4	63·7	84·2	70·9	77·7	72·8	74·4	72·2
March	100·2	61·3	79·9	68·1	74·7	70·3	72·5	70·4
April	82·5	54·9	69·1	60·5	66·9	63·5	67·0	65·0
May	69·7	49·8	60·8	54·4	60·3	57·7	61·4	59·8
June	62·7	46·4	55·2	50·0	55·1	52·7	56·4	55·1
July	60·9	45·5	53·5	48·6	53·2	50·9	54·1	52·8
August	64·6	46·5	56·0	50·0	54·4	51·9	54·5	53·0
September	73·2	49·5	61·9	53·8	58·7	55·5	57·5	55·8
October	83·6	53·8	69·2	58·5	64·3	60·2	61·9	60·0
November	95·2	58·8	77·1	64·2	70·5	65·7	66·9	64·7
December	104·9	62·4	82·9	69·0	75·3	70·1	71·2	68·9
Mean	84·4	54·7	69·6	60·0	65·8	62·0	64·3	62·4

* Records incomplete for 1949. 24 year means.

Wind velocity at eight feet from the ground from cup anemometer for years 1948 and 1949. Waite Institute. Miles per month.

Month	1948	1949	Twelve Years Mean, 1938-1949
January	97	104	105
February	108	93	104
March	105	90	91
April	70	80	82
May	64	59	71
June	62	53	75
July	84	81	88
August	98	86	91
September	94	79	97
October	95	109	96
November	112	93	97
December	97	86	102
Mean	91	84	92

General Climatological Data.

The most important data on which studies of climatology as applied to agriculture and biology are to be based, involve rainfall, evaporation, temperature, relative humidity, and atmospheric saturation deficit.

Evaporation from a free water surface is dependent on saturation deficit, sunshine and wind. Estimates of evaporation have usually been made in the work of the Waite Institute on the assumption that it is proportional to saturation deficit when comparisons made for two or more localities relate to the same month. The ratios of precipitation (rainfall) to evaporation or saturation deficit have been found of special value in agro-climatological or bioclimatological studies. A ratio of more universal application has been found to be

that of precipitation of the 0·75th power of evaporation or atmospheric saturation deficit and this ratio is being increasingly applied and tested. The essential data for the Waite Institute based on the mean values for the 25 years 1925–1949 are given in the following tables.

Climatological data for the Waite Institute. Mean of 25 years 1925-1949.

Month	Precipitation inches	Evaporation inches	Temperature Max. °F.	Temperature Min. °F.	Temperature Mean °F.	Relative humidity per cent.	Bright sunshine hours per day
January	0·99	8·56	81·4	60·1	70·7	49	8·8
February	1·24	6·98	80·7	60·6	70·6	52	8·4
March	0·92	6·41	78·2	59·4	68·8	52	7·5
April	2·03	3·97	70·2	54·2	62·2	62	5·6
May	2·90	2·71	64·1	50·6	57·4	68	4·2
June	2·83	1·74	58·7	46·4	52·5	75	3·2
July	3·10	1·75	57·3	45·3	51·3	75	3·2
August	3·08	2·31	59·3	45·9	52·6	70	4·5
September	2·57	3·24	63·8	48·1	55·9	65	5·7
October	2·15	4·60	68·2	50·7	59·4	60	6·6
November	1·52	6·10	74·0	54·7	64·4	54	7·6
December	1·14	7·77	78·8	57·8	68·3	50	8·3
Total	24·47	56·14	Mean 69·6	52·8	61·2	61	6·1

Calculated on the basis of a standard month of 30·4 days.

Month	Precipitation (P) inches	Evaporation (E) inches	Saturation deficit (s.d.) inches of mercury	P/E.	P/sd.	$P/E.^{.75}$	$P/sd.^{.75}$
January	0·97	8·38	0·386	0·115	2·51	0·196	1·98
February	1·33	7·52	0·362	0·177	3·67	0·293	2·85
March	0·90	6·28	0·341	0·144	2·65	0·227	2·02
April	2·06	4·02	0·215	0·512	9·56	0·726	6·52
May	2·85	2·66	0·152	1·071	18·80	1·369	11·72
June	2·87	1·76	0·099	1·629	29·00	1·876	16·21
July	3·04	1·71	0·095	1·775	32·00	2·028	17·76
August	3·02	2·27	0·123	1·327	24·55	1·631	14·51
September	2·60	3·28	0·157	0·792	16·55	1·066	10·43
October	2·11	4·51	0·205	0·469	10·28	0·682	6·93
November	1·54	6·17	0·281	0·249	5·47	0·392	3·99
December	1·11	7·62	0·348	0·146	3·20	0·243	2·46
Total	24·40	56·18	Mean 0·230	—	—	—	—

Characteristics of the Rainfall at the Waite Institute.

Daily rainfall observations have been taken at the Institute since 1925 and automatic recordings since 1939. Although these records are of short duration, any generalizations reached from a consideration of the data can be checked by reference to the records of Adelaide, four miles away, with an observation period of 111 years. The rainfall at the Institute is 3·4 inches per annum more than at the Meteorological Bureau, Adelaide.

The following table gives the mean values for 25 years of the number of days on which rainfall was recorded in each month, the mean rainfall for each wet day and the mean daily rainfall.

Some rainfall characteristics at the Waite Institute. Mean values for the years 1925-1949.

Month	Number of days in which rainfall was recorded	Rainfall per wet day inches	Mean daily rainfall inches
January	6·0	·165	·032
February	6·3	·197	·044
March	6·3	·146	·030
April	12·2	·166	·068
May	15·4	·189	·094
June	18·5	·153	·094
July	21·2	·146	·100
August	19·3	·160	·099
September	17·1	·150	·086
October	14·7	·146	·069
November	10·1	·150	·050
December	7·5	·152	·037
Total	154·6	Mean ·158	·067

The distribution over the 25 years of the number of months in which rain fell on the number of days indicated is given in the following table. Only on one occasion (in January, 1926) in this period has there been a month without any rainy day. On one occasion (July, 1932) 4 days only out of the 31 were without rain.

Number of months in 25 years in which rain has fallen on the number of days indicated. Waite Institute: 1924-1949

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
January	1	–	2	2	4	4	1	5	–	–	3	3				
February			1	2	7	5	3	–	–	1	2	2	–	1	–	1
March		1	4	1	1	4	3	3	1	2	2	1	1	1		
April				1	–	1	–	1	3	2	1	1	3	2	4	1
May				1	–	–	1	–	–	1	1	–	3	1	2	3
June													1	3	2	2
July															1	–
August									1	–	–	–	–	2	–	1
September												3	1	2	1	–
October						1	1	–	–	1	2	1	1	–	5	2
November				1	1	1	2	2	3	2	1	2	3	1	2	2
December		1	1	–	3	–	3	6	4	1	–	3	1	2		

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31 days
January																
February																
March																
April	–	1	–	1	–	–	1	1								
May	1	2	2	2	1	1	1	–	1	1						
June	1	1	2	1	2	1	5	2	1	1						
July	–	1	3	5	–	4	2	1	3	3	1	1				
August	–	3	2	2	4	5	–	–	3	1	1					
September	7	–	3	1	–	3	1	2	–	–	1					
October	3	1	1	3	1	–	2									
November	1	–	1													
December																

The calculations in this section are due to Mr. H. E. Mansbridge.

An expression of the trend through the year of mean daily rainfall can also be obtained by fitting a suitable curve to the daily rainfall data. For this purpose the mean rainfall for the 25 years was calculated for each day of the year and these again grouped as six day means for 61 successive periods. To these 61 points a polynomial of the fifth degree was fitted. This was significant to the fourth degree. Fig. 1 shows the curve so obtained superposed upon the 366 daily averages. The graph has a minimum towards the end of January and a maximum in the middle of July, the ascending portion being approximately a fortnight less in duration than the descending portion.

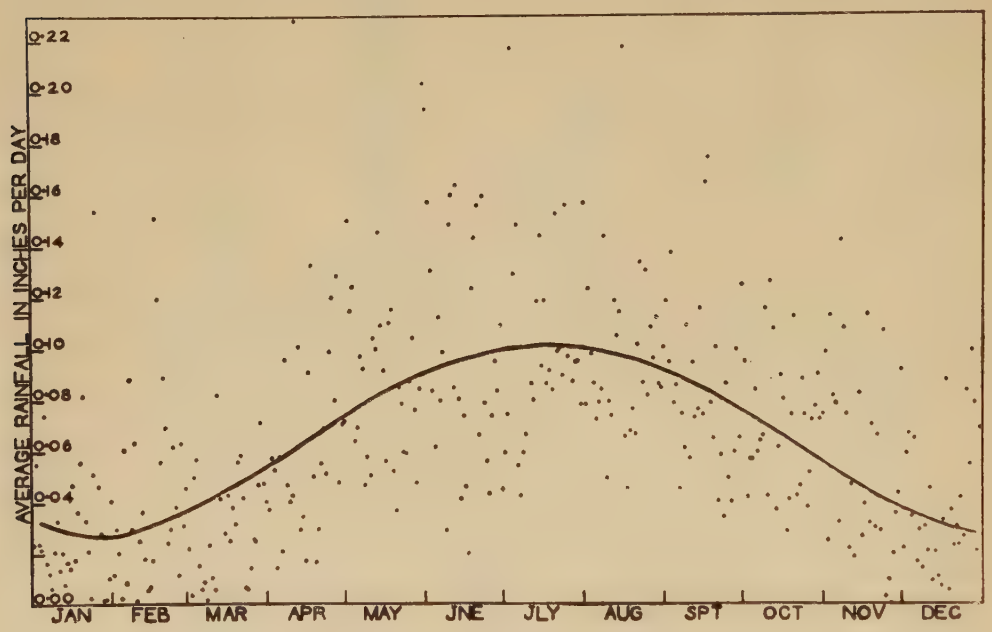

Fig. 1. Rainfall at the Waite Institute 1925–1949.
The distribution over the year of the daily rainfall averaged over the years 1925–1949.

When a Fourier series is applied to the polynomial curve of rainfall and comparisons are made between the curves for solar radiation, temperature and rainfall through the year, the temperature curve is found to be 33 days behind that for radiation and the rainfall curve is 175 days later than that for temperature. The maximum temperature occurs near January 25th and the minimum near July 24th. In the case of rainfall the maximum occurs near July 19th and the minimum near January 16th.

Expectation of rainfalls of maximum intensities in relation to duration of storms.

The maximum falls of rain recorded at the Institute during the period of observation, for a given duration are recorded in the following table.

Maximum falls recorded at the Waite Institute.

Period	Calendar day record	Continuous record	Date	
3 days	4·09		Apr. 16-18	1938
2 days	3·66		Apr. 16-17	1938
1 day	2·67		Feb. 17	1943
3 days		3·35	Jan. 24-26	1941
2 days		3·11	Jan. 24-26	1941
1 day		2·57	Feb. 17	1943
360 mins.		2·28	Feb. 17	1943
60 mins.		1·26	Feb. 17	1943
30 mins.		0·72	Feb. 17	1943
15 mins.		0·60	May 31	1942
10 mins.		0·60	May 31	1942
5 mins.		0·50	May 31	1942

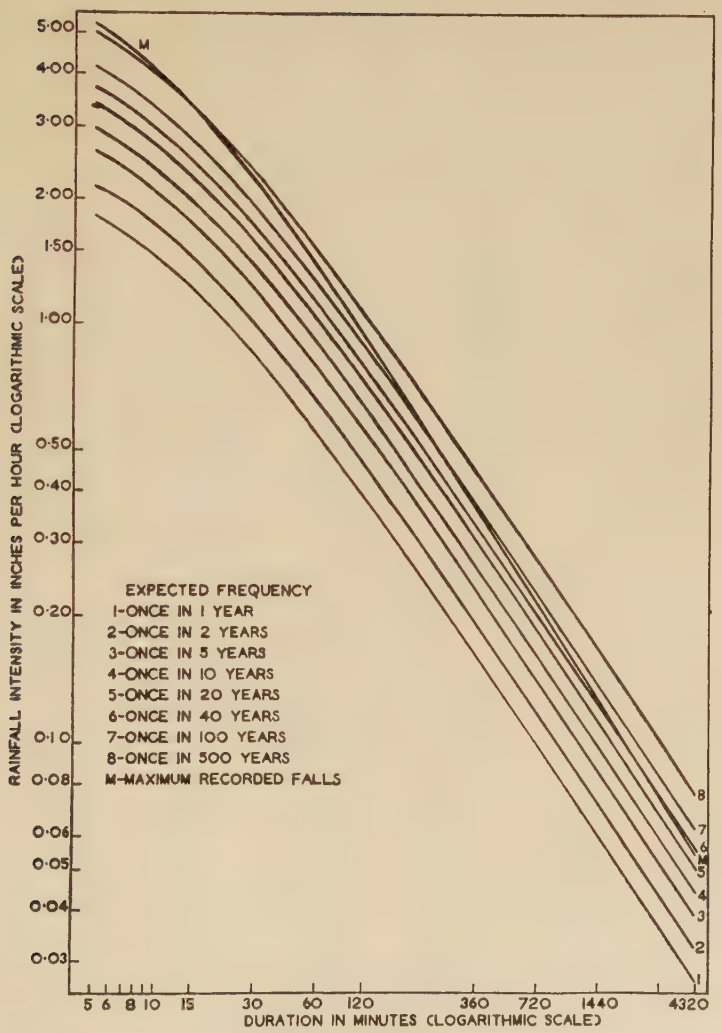

Fig. 2. Tentative maximum rainfall intensity diagram for the Waite Institute.

The equation of the standard form relating intensity and period for the data has been determined. This is:

$$I=36\cdot9/(t+7)^{0\cdot78}$$

Where I is rainfall intensity in inches per hour and t is the period of time during which the rainfall is recorded.

The general rainfall intensity equation for the Waite Institute has been tentatively determined as:

$$Iy=13\cdot37F/(t+8)^{0\cdot724}$$

in which $F=24\cdot05y^{0\cdot01}\,23\cdot17$.

Iy is the maximum intensity in inches per hour for periods of t minutes in y years, and F is the frequency function.

The expected frequency of maximum rainfall intensities derived from the above equations is illustrated in Fig. 2, together with the curve (M) derived from the maximum recorded falls actually observed.

OBSERVATIONS AT COUNTRY CENTRES.

(1) PALLAMANA.

Monthly rainfall and evaporation in inches for years 1948-1949.

Month	Rainfall 1948	Rainfall 1949	Evaporation 1948	Evaporation 1949
January	0·07	0·26	11·27	9·45
February	0·35	1·28	9·12	7·10
March	0·24	0·03	7·45	7·49
April	2·87	0·40	3·79	4·70
May	0·68	1·95	2·77	2·51
June	1·04	1·59	1·69	1·68
July	1·76	1·54	2·12	2·01
August	1·25	0·83	2·79	2·69
September	0·43	0·59	4·93	3·99
October	1·57	1·70	6·89	5·73
November	1·70	1·79	6·93	6·03
December	1·70	0·01	9·34	9·32
Total	13·66	11·97	69·08	62·71

Mean monthly values for the period 1938-1949.

Month	Rainfall inches	Evaporation inches	Mean air temperature °F.	Mean relative humidity per cent.	Mean wind velocity at 8 feet miles per day
January	1·18	10·35	69·7	51	201
February	0·92	8·29	68·6	58	187
March	0·62	7·65	66·2	60	170
April	1·29	4·49	59·8	72	144
May	1·19	2·89	54·9	79	134
June	1·21	1·98	50·3	84	130
July	1·47	2·01	49·5	84	150
August	1·28	2·84	50·6	79	157
September	1·12	4·28	54·6	68	169
October	1·15	6·17	58·4	61	172
November	1·47	7·50	63·2	56	187
December	1·23	9·86	67·6	49	195
Total	14·13	68·29	Mean 59·4	67	166

(2) YUDNAPINNA.

Monthly rainfall and evaporation in inches for the years 1948-1949

Month	Rainfall		Evaporation	
	1948	1949	1948	1949
January	0·02	0·00	14·51	14·27
February	0·16	1·54	12·29	9·85
March	0·00	0·00	9·80	10·25
April	0·39	0·20	6·16	6·34
May	0·13	2·09	4·00	3·56
June	0·44	0·22	2·56	2·08
July	0·25	0·64	3·55	2·75
August	0·27	0·11	4·84	4·59
September	0·00	1·41	7·61	5·21
October	0·53	2·49	9·69	7·71
November	0·48	0·97	11·58	9·76
December	1·65	0·24	12·82	14·09
Total	4·32	9·91	99·41	90·46

Mean monthly values for the period 1939-1949.

Month	Rainfall inches	Evaporation inches	Mean air temperature °F.	Mean relative humidity per cent.
January	0·68	14·31	77·7	46
February	1·41	11·46	76·0	49
March	0·56	10·26	71·9	47
April	0·43	6·51	63·5	59
May	0·65	4·22	57·6	65
June	0·76	2·69	51·9	75
July	0·68	3·04	50·7	74
August	0·56	4·24	53·9	64
September	0·45	6·43	58·9	53
October	0·85	8·94	64·3	46
November	0·69	11·03	70·1	44
December	0·94	13·03	75·2	41
Total	8·67	96·17	Mean 64·3	55

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Records of Field Experimental Work

LIST OF FIELD EXPERIMENT RECORDS.

1. Permanent Rotation Experiment. 1926–49.
2. Influence of Grazed and Harvested Forage Crops on the Yield of Temporary Pasture and Wheat in Four-Course Rotations. 1937–1949.
3. Time and Rate of Seeding of Field Peas, 1944–1949.
4. Influence of Top Dressing on the Yield and Carrying Capacity of Natural Pasture, 1925–1949.
5. Yield Trials of Crossbred Wheats and Varieties, Waite Institute, 1948.
6. Yield Trials of Crossbred Wheats and Varieties, Waite Institute, 1949.
7. Yield Trials of Crossbred Wheats and Varieties, Saddleworth, 1948–49.
8. Yield Trials of Pea Varieties, 1948.
9. Yield Trials of Pea Varieties, 1949.
10. Crop Rod Row Trial 1949, Waite Institute.
11. Safflower Variety Trails, 1948.
12. Flax Variety Trial (A), Waite Institute, 1948.
    Flax Variety Trial (B), Waite Institute, 1948.

1. PERMANENT ROTATION EXPERIMENT, 1926-1949.

Effect of different crop rotations on the yield of wheat.

A number of the original rotations in this experiment were discontinued as from 1947, and these are being replaced by modern rotations involving longer periods under sown pasture. It will, however, be some years before the results of the new rotations are applicable and consequently the yields are not included in the Table. The original numbers of the rotations which have been continued are retained for reference.

Variety of crop and seed rate per acre: Sepoy wheat (1926-34), Seewari (1935-47) and Seewari 48 (1948-49), 80-90 lb.; Early Burt oats, 60-70 lb.; Pryor barley, 70-80 lb.; White Brunswick peas, 120-150 lb.; Wimmera ryegrass, 10-15 lb. (1926-45); Wimmera ryegrass, 3 lb. + Fulghum oats, 40 lb. (1946-49).

Basal dressing of superphosphate 187 lb. per acre (1929-42), 94 lb. per acre (1944-49).

Design: Unreplicated, but each course of all rotations is represented every year.

Area of each plot = 1/7th acre (1926-37) $1/7.619$ acre (1938-49).

(a) Total yields of crop and pasture in cwt. air-dry material per acre.

Rotation	Crop	Mean 1926-47	1948	1949	Mean 1926-49
1	Fallow				
	Wheat	**50·28**	**28·10**	**43·66**	**49·08**
2	Peas	30·01	9·72	34·08	29·33
	Wheat	**38·00**	**35·20**	**45·52**	**38·20**
3	Fallow				
	Wheat	**58·89**	**43·65**	**65·68**	**58·54**
	Rye-grass	29·79	39·27	36·29	30·46
4	Fallow				
	Wheat	**56·80**	**47·97**	**56·23**	**56·41**
	Oats	40·00	26·09	32·85	39·12
7	Wheat	**25·44**	**24·53**	**25·43**	**25·40**
10	Fallow				
	Wheat	**68·08**	**57·14**	**81·43**	**68·18**
	Oats	49·79	27·75	36·67	48·33
	Rye-grass	32·76	37·78	54·00	33·85
12	Fallow				
	Wheat	**55·64**	**38·34**	**53·13**	**54·81**

(b) Grain yields in bushels per acre.

1	Fallow				
	Wheat	**34·39**	**17·80**	**32·25**	**33·61**
2	Peas	20·37	7·84	grain failure	19·00
	Wheat	**26·31**	**24·25**	**31·76**	**26·45**
3	Fallow				
	Wheat	**40·08**	**35·33**	**53·07**	**40·42**
	Rye-grass*				
4	Fallow				
	Wheat	**35·72**	**37·04**	**43·78**	**36·11**
	Oats	42·58	18·05	33·87	41·20
7	Wheat	14·70	14·98	9·04	**14·48**
10	Fallow				
	Wheat	**44·88**	**43·62**	**66·09**	**45·71**
	Oats	54·40	18·62	36·20	52·15
	Rye-grass*				
12	Fallow				
	Wheat	**37·75**	**27·27**	**38·42**	**37·34**

* Yields (cwt. per ac.) in previous table.

2. INFLUENCE OF GRAZED AND HARVESTED FORAGE CROPS ON THE YIELD OF TEMPORARY PASTURE AND WHEAT IN FOUR-COURSE ROTATIONS, 1937-1949.

On the completion of two cycles of the experiment two of the original rotations were modified, and as a consequence an interval of one year elapsed before the results of the new rotations became applicable.

Original rotations:

Two cycles	A	B	C	D	E
	Fallow	Fallow	Fallow	Fallow	Fallow
1940-47	Wheat	Wheat	Wheat	Wheat	Wheat
1937-44	Peas	Clover	Barley	Oats	Fallow
1938-45	W.R.G. Pasture	W.R.G. Pasture	W.R.G. Pasture	W.R.G. Pasture	Wheat

Present rotations:

1st cycle	A	B	C	D	E
	Fallow	Fallow	Fallow	Fallow	Fallow
1949-52	Wheat	Wheat	Wheat	Wheat	Wheat
1946-49	Peas	Peas	Oats with S/A	Oats	Fallow
1947-50	W.R.G. Pasture	Grazing Oats	W.R.G. Pasture	W.R.G. Pasture	Wheat

Results for the original treatments at the end of two cycles were given in the last Report, and the details and yields given below relate only to the unaltered and new rotations.

Variety of crop and seed rate per acre: Seewari 48 wheat, 80-90 lb.; Mulga oats, 60-70 lb.; White Brunswick peas, 120-150 lb.; Fulghum grazing oats, 60-70 lb.; Wimmera rye-grass, 10 lb.

Fertilizer: Basal superphosphate applied at 1 cwt. per acre to all crops and pastures. Sulphate of ammonia at 2 cwt. per acre applied to oats in rotation C.

Forage crop treatment: G = grazed. H = harvested.

Design: 60 main plots in 4 groups of 15 plots, each group representing one course of the rotations. The groups of 15 plots are divided into 3 randomized blocks in which each rotation is represented by a plot. The plots are subdivided into halves; on one half the forage crop is grazed, and on the other it is harvested.

Area of main plots = $\frac{1}{6.94}$ acre.

(a) Yields of forage crops (air-dry).

	A			B			C			D		
	Peas			Peas			Oats (2 cwt. S/A)			Oats		
	G	H		G	H		G	H		G	H	
Year	(cwt.)	(cwt.)	(bush.)	(cwt.)	(cwt.)	(bush.)	(cwt.)	(cwt.)	(bush.)	(cwt.)	(cwt.)	(bush.)
Mean 1937-44	46·11	39·80	30·29	—	—	—	—	—	—	19·25	20·85	23·09
1945	47·47	28·44	26·23	—	—	—	—	—	—	17·78	20·27	22·17
1946	60·42	48·59	44·62	58·33	56·38	51·45	32·64	24·36	22·71	3·08	1·86	1·49
1947	66·22	38·71	30·67	63·80	40·70	34·62	70·80	71·27	67·16	39·43	27·08	30·07
1948	56·72	36·65	37·82	43·34	43·92	40·73	14·20	13·76	17·41	1·61	1·88	—
1949	31·40	9·89	3·91	38·65	18·03	10·87	30·25	24·43	27·56	8·36	3·03	3·45
Mean 1946-49	53·69	33·46	29·26	51·03	39·76	34·42	36·97	33·46	33·71	13·12	8·46	8·75

(b) Yields of temporary pasture (air-dry) in cwt. per acre.

Year	A W.R.G. after peas G	A W.R.G. after peas H	B Oats after peas G	B Oats after peas H	C W.R.G. after oats with S/A G	C W.R.G. after oats with S/A H	D W.R.G. after oats G	D W.R.G. after oats H
Mean 1938-45	51·35	33·43	—	—	—	—	14·44	10·71
1946	76·36	53·18	—	—	—	—	13·56	11·80
1947	56·37	35·37	73·28	41·34	15·05	9·75	9·92	7·08
1948	48·56	28·21	48·36	39·85	35·38	8·73	19·73	6·80
1949	31·25	22·89	50·11	43·35	4·95	4·00	5·01	3·99
Mean 1947-49	45·39	28·82	57·25	41·51	18·46	7·49	11·55	5·96

(c) Yields of wheat in bushels per acre.

Year	A G	A H	B G	B H	C G	C H	D G	D H	E G	E H
Mean 1940-47	43·49	41·59	—	—	—	—	37·42	35·26	32·69	31·05
1948	41·55	27·46	—	—	—	—	15·43	13·66	11·25	10·91
1949	57·36	49·67	57·73	51·15	43·84	38·64	38·87	36·48	42·46	38·31

3. TIME AND RATE OF SEEDING OF FIELD PEAS, 1944–1948.

Variety: White Brunswick.

Seed rate: 60, 90, 120, 150 lb. per acre except in 1944 and 1945 when 65 and 95 lb. were sown.

Superphosphate: Basal dressing of 1 cwt. per ac.

Time of sowing: Actual dates 1944, E = 16th May, M = 14th June, L = 11th July. In subsequent years the sowings were made in same three months as closely as practicable to the above dates.

Treatments: All combinations of seed rates and time of sowing.

Design: 4 randomized blocks of 3 main plots sown early, mid-season and late, respectively. Each main plot split into 4 sub-plots sown at 4 different seed rates. Total plots 48, complete replication 4.

Area of main plot: $\frac{1}{7.86}$ ac.

(a) Total Produce (cwt. per acre).

Year	Rate of Seeding. 60 lb.	90 lb.	120 lb.	150 lb.	Mean
		Early Sowing.			
1944	18·36	21·75	24·71	25·26	**22·52**
1945	40·90	39·78	38·59	35·49	**38·69**
1946	46·48	50·25	55·38	59·11	**52·81**
1947	66·97	70·31	61·19	60·79	**64·82**
1948	42·39	50·98	50·07	53·05	**49·12**
Mean	**43·02**	**46·61**	**45·99**	**46·74**	**45·59**
		Mid-season Sowing.			
1944	6·87	9·82	11·21	12·17	**10·02**
1945	29·57	33·93	32·50	37·64	**33·41**
1946	34·45	38·69	40·54	45·23	**39·73**
1947	67·03	68·63	67·26	66·06	**67·25**
1948	27·69	36·45	42·06	36·91	**35·78**
Mean	**33·12**	**37·50**	**38·71**	**39·60**	**37·24**
		Late Sowing.			
1944	2·48	3·49	3·96	4·57	**3·63**
1945	23·10	28·68	32·25	35·46	**29·87**
1946	24·42	27·08	33·82	37·35	**30·67**
1947	60·82	65·23	66·23	66·23	**64·63**
1948	26·35	29·53	34·54	35·64	**31·52**
Mean	**27·43**	**30·80**	**34·16**	**35·85**	**32·06**
Means of times and years	**34·53**	**38·31**	**39·62**	**40·73**	**38·30**

Results of analyses with standard errors for comparing means.

	Time	Rate	Time × rate
1944	***	***	***
S.E.	2·673	0·841	1·456
1945	**	**	***
S.E.	5·939	1·813	3·139
1946	***	***	—
S.E.	6·654	1·534	2·657
1947	—	—	—
S.E.	2·768	2·415	4·182
1948	***	***	*
S.E.	4·011	1·422	2·464

(b) Grain (bushels per acre).

Year	Rate of Seeding. 60 lb.	90 lb.	120 lb.	150 lb.	Mean
		Early Sowing.			
1944	18·12	21·10	23·49	23·85	**21·64**
1945	31·11	26·20	25·72	22·92	**26·49**
1946	43·64	47·59	49·54	52·78	**48·39**
1947	61·67	64·03	53·19	52·69	**57·90**
1948	42·71	47·95	45·58	48·70	**46·24**
Mean	**39·45**	**41·37**	**39·50**	**40·19**	**40·13**
		Mid-season Sowing.			
1944	7·09	10·59	11·86	12·47	**10·50**
1945	20·16	24·58	23·02	26·67	**23·61**
1946	34·44	39·34	40·57	44·47	**39·70**
1947	64·41	66·72	65·85	63·60	**65·15**
1948	25·57	35·36	41·40	35·23	**34·39**
Mean	**30·33**	**35·32**	**36·54**	**36·49**	**34·67**
		Late Sowing.			
1944	1·64	2·25	2·49	2·80	**2·29**
1945	18·38	22·39	26·56	28·59	**23·98**
1946	24·80	27·81	34·16	36·89	**30·91**
1947	60·86	65·66	65·78	67·03	**64·83**
1948	23·82	28·49	34·11	35·05	**30·37**
Mean	25·90	29·32	32·62	34·07	30·48
Means of times and years	**31·89**	**35·34**	**36·22**	**36·92**	**35·09**

Results of analyses with standard errors for comparing means.

	Time	Rate	Time × rate
1944	***	***	***
S.E.	1·120	0·517	0·895
1945	—	*	***
S.E.	2·002	0·860	1·490
1946	***	***	—
S.E.	3·527	0·850	1·473
1947	**	—	*
S.E.	1·732	1·261	2·183
1948	***	***	**
S.E.	2·617	0·817	1·416

* = significant at $P < \cdot001$.
** = significant at $P < \cdot01$.
*** = significant at $P < \cdot05$.

4. INFLUENCE OF TOP DRESSING ON THE YIELD AND CARRYING CAPACITY OF NATURAL PASTURE, 1925-1949.

Investigation commenced in 1925 on unimproved natural grassland dominated by *Danthonia* spp.

Manurial treatments:

A. Superphosphate, 185 lb. (40 lb. P_2O_5) per acre.
B. Superphosphate, 185 lb. and nitrate of soda, 78 lb. (12½ lb N.) per acre.
C. Nil.
D. Ground rock phosphate, 103 lb. (40 lb P_2O_5) per acre.
E. Basic slag, 260 lb. (40 lb. P_2O_5) per acre.

Design: Single replication of each treatment.

Area of plot: $^{13}/_{15}$th acre subdivided into 5 equal sections grazed in rotation by Merino wethers.

Total yield in cwt. air-dry herbage per acre.

Year	Treatment. A	B	C	D	E	Mean A-E
1925	27·74	30·69	21·76	18·57	25·49	**24·85**
1926	43·20	43·57	28·35	27·16	49·15	**38·29**
1927	28·54	27·95	18·00	15·95	24·84	**23·06**
1928	39·63	41·81	24·31	27·89	35·58	**33·84**
1929	33·70	37·45	17·69	25·63	35·31	**29·96**
1930	30·32	39·86	20·67	30·56	43·56	**32·99**
1931	47·50	63·12	41·43	52·60	58·06	**52·54**
1932	75·66	81·11	56·92	70·34	78·25	**72·46**
1933	64·70	63·58	51·43	61·72	57·61	**59·81**
1934	38·00	52·44	20·23	43·66	48·67	**40·60**
1935	72·90	70·90	41·49	58·25	62·72	**61·25**
1936	42·24	48·67	29·54	47·30	41·15	**41·78**
1937	51·69	59·09	36·21	59·48	61·07	**53·51**
1938	54·47	57·62	34·92	60·11	64·06	**54·24**
1939	50·57	66·37	48·97	63·36	62·40	**58·33**
1940	26·48	30·30	29·48	33·86	28·41	**29·71**
1941	37·04	42·83	35·64	46·32	43·77	**41·12**
1942	54·74	70·14	45·17	66·08	65·26	**60·28**
1943	63·43	65·60	56·34	58·66	81·30	**65·07**
1944	44·43	47·80	35·95	54·59	51·54	**46·86**
1945	50·88	54·48	39·67	59·42	60·80	**53·05**
1946	66·24	60·46	56·18	71·32	69·96	**64·83**
1947	62·88	64·22	45·48	63·62	72·90	**61·82**
1948	67·73	82·37	55·32	101·98	96·65	**80·81**
1949	71·20	92·49	45·75	84·14	92·13	**77·14**
Mean 1925-49	**49·84**	**55·80**	**37·48**	**52·10**	**56·43**	**50·33**

Yield of legumes in the pasture cwt. air-dry herbage per acre.

Year	Treatment. A	B	C	D	E	Mean A-E
1925	20·25	18·35	6·57	5·64	14·35	13·03
1926	20·17	16·66	9·49	9·18	19·12	14·92
1927	4·29	0·40	1·02	0·44	2·43	1·72
1928	23·00	13·78	0·90	3·81	4·28	9·15
1929	14·45	8·24	2·18	4·74	13·30	8·58
1930	1·71	0·54	0·39	1·57	1·63	1·17
1931	6·80	2·79	3·56	5·33	5·18	4·73
1932	9·35	7·33	9·94	18·01	12·58	11·44
1933	5·40	2·23	4·20	4·24	3·10	3·83
1934	1·89	1·17	2·34	1·95	0·06	1·48
1935	44·53	27·97	10·14	20·69	18·63	24·39
1936	7·84	14·89	8·82	15·08	9·95	11·32
1937	19·30	15·15	9·69	14·63	31·34	18·02
1938	14·31	4·40	6·83	17·50	15·85	11·78
1939	6·85	4·13	12·73	17·73	11·26	10·54
1940	5·48	4·43	3·16	1·83	3·37	3·65
1941	9·73	3·62	2·54	1·45	2·06	3·88
1942	2·58	3·40	3·37	1·45	3·00	2·76
1943	7·80	11·05	6·04	5·82	14·27	9·00
1944	1·37	0·55	3·52	7·24	1·65	2·87
1945	16·98	17·69	4·95	2·18	8·79	10·12
1946	14·12	4·44	10·11	15·53	8·48	10·54
1947	29·98	22·25	13·98	26·58	25·35	23·63
1948	6·68	3·15	17·69	30·23	11·00	13·75
1949	29·22	35·41	8·34	22·73	25·19	24·18
Mean 1925-49	**12·96**	**9·76**	**6·50**	**10·22**	**10·65**	**10·02**

Stock-carrying capacity. Sheep days of grazing per acre.

	Treatment. A	B	C	D	E
Mean 1928-47	1,574	1,711	1,096	1,528	1,643
1948	2,195	2,592	1,689	2,611	2,622
1949	1,638	2,023	1,135	1,978	2,362
Mean 1928-49	**1,605**	**1,765**	**1,125**	**1,598**	**1,720**

5. YIELD TRIALS OF CROSSBRED WHEATS AND VARIETIES. WAITE INSTITUTE, 1948.

I. *Early Sown Large Field Plots.*

Date of sowing: June 4th.
Seed rate: 80 lb./ac.
Superphosphate: 1 cwt./ac.

Area of plot: 1/69th acre.
Design: Randomized block of four replications.

Variety	Mean yield bush./acre
1. Quadrat	34·5
2. Diadem	33·1
3. Seewari	33·1
4. Ghurka	33·0
5. Pinnacle	32·6
6. (Gluyas x Hope) x Ghurka x Ghurka x Ghurka (43-36)	30·5
7. Seewari 48	29·4
8. Kenya x Ghurka (41-142)	27·5
9. Gabo x Ghurka x Ghurka x Ghurka x Ghurka (2705)	26·4
10. Nabawa x Riverina x Hope (38-356)	21·0

Differences between two means of 3·5 bush./acre are significant at 5 per cent. level of probability.

Germination of some plots very poor, especially N.R.H. (38-356).

II. *Early mid-season Sown Large Field Plots.*

Date of Sowing: June 11th.
Seed rate: 80 lb./ac.
Superphosphate: 1 cwt./ac.

Area of plot: 1/67 acre.
Design: Randomized block of four replications.

Variety	Mean yield bush./acre
1. (Kenya x Ghurka) x (Gluyas x Hope) x Ghurka x Ghurka (43-62)	44·2
2. Gabo x Dundee^3 (716)	42·8
3. Dundee	42·7
4. Kendee	42·4
5. Ridley	42·4
6. Ridley 48	41·8
7. Kenya x Dundee (40-109)	41·7
8. Dundee 48	40·8
9. Warigo	38·5
10. Celebration	36·8

Differences between two means of 3·7 bush./acre are significant at 5 per cent. level of probability.

III. *Mid-season Sown Large Field Plots.*

Date of sowing: June 16th.
Seed rate: 80 lb./ac.
Superphosphate: 1 cwt./ac.

Area of plot: 1/67th acre.
Design: Randomized block of four replications.

	Variety	Mean yield bush./acre
1.	Insignia	41·3
2.	Javelin	40·1
3.	Javelin 48	39·4
4.	Gabo x Ranee x Ranee x Ranee x Ranee (45S-60)	38·2
5.	Glenwari	37·6
6.	Warigo	36·8
7.	Gabo x Ranee x Ranee x Ranee (2714)	36·4
8.	Ranee	36·2
9.	Kendee	36·2
10.	Yalta	33·9

Differences between two means of 3·6 bushels per acre are significant at 5 per cent. level of probability.

IV. *Late Sown Large Field Plots.*

Date of sowing: June 29th.
Seed rate: 88 lb./ac.
Superphosphate: 1 cwt./ac.

Area of plot: 1/67 acre.
Design: Randomized block of four replications.

	Variety	Mean yield bush./acre
1.	Gabo x Dirk[3] (726)	37·9
2.	Dirk	36·5
3.	(Gluyas x Hope) x Ranee x Ranee (42-79)	35·7
4.	Insignia	35·4
5.	Kenya x Federation[4] (2780)	34·8
6.	(Gluyas x Hope) x Ranee x Ranee x Ranee (43-28)	34·1
7.	White Federation 38	33·6
8.	Dirk 48	33·3
9.	Gabo	30·5
10.	White Federation 45	30·2

Differences between two means of 3·4 bushels per acre are significant at 5 per cent. level of probability.

Small Field Plots.

Date of sowing: June 30th.
Seed rate: 88 lb./ac.
Superphosphate: 1 cwt./ac.

Area of plot: 1/84 acre.
Design: Randomized blocks of four replications.

I. *Back-cross Seewari and Ghurka and their parent types.*

Variety	Mean yield bush./acre
1. Ghurka	59·9
2. Gabo x Ghurka x Ghurka x Ghurka x Ghurka (45S-64)	56·1
3. Seewari 48	55·6
4. Seewari	51·9

"z" test not significant.

II. *Back-cross Ridley and Dundee and their parent types.*

Variety	Mean yield bush./acre
1. Ridley 48	54·8
2. Dundee	53·0
3. Ridley	52·9
4. Dundee 48	51·9

"z" test not significant.

III. *Back-cross Javelin and Ranee and their parent types.*

Variety	Mean yield bush./acre
1. Javelin	54·1
2. Javelin 48	52·5
3. Ranee	47·1
4. Gabo x Ranee x Ranee x Ranee x Ranee	44·7

Differences between two means of 4·6 bushels per acre are significant at 5 per cent. level of probability.

IV. *Back-cross Dirk and Scimitar and their parent types.*

Variety	Mean yield bush./acre
1. Dirk	48·5
2. Dirk 48	44·1
3. Scimitar 48	40·3
4. Scimitar	38·1

Differences between two means of 6·5 bush./acre are significant at the 5 per cent. level of probability.

6. YIELD TRIALS OF CROSSBRED WHEATS AND VARIETIES. WAITE INSTITUTE, 1949.

Date of sowing: July 22nd.
Harvested: December 29th.
Seed rate: 80 lb./ac.
Superphosphate: 112 lb./ac.

Area of plots: $\frac{1}{220}$th acre.
Design: Randomized blocks of four replications.

Variety	Mean yield bush./acre
Scimitar 48	31·2
Bencubbin 48	30·7
Rapier 48	30·4
Scimitar	29·5
Rapier	27·9
Insignia 49	25·1
Bencubbin	25·0
Insignia	23·9

Difference between two means of 2·8 bushels per acre are significant at 5 per cent. level of probability.

Note: Heavy rains in October resulted in much secondary growth which became rusted in November.

7. YIELD TRIALS OF CROSSBRED WHEATS AND VARIETIES.

a. Saddleworth, 1948-49.

Variety	Mean yield bush./acre 1948	1949
Dirk	52·7	33·4
Dirk 48	54·2	33·7
Gabo x Dirk x Dirk x Dirk (726)	—	33·9
Warigo	49·9	31·3
Frisco	—	34·4
Diadem	52·1	—
Kendee	50·4	38·6
Insignia	55·1	35·3
Quadrat	55·9	36·7
(Kenya x Ghurka) x (Gluyas x Hope) x Ghurka x Ghurka (43-62)	54·3	35·7
Gabo x Ghurka x Ghurka x Ghurka x Ghurka (2705)	53·5	30·0
Kenya x Ghurka (41-42)	50·0	—
(Gluyas x Hope) x Ghurka x Ghurka x Ghurka (43-46)	50·7	—
Kenya x Dundee (40-109)	52·1	—
Necessary difference between means for significance at 5 per cent. level of probability.	2·5	3·0

b. Pallamana, 1948-49.

Variety	Mean yield bush./acre 1948	1949
Insignia	30·3	18·2
Glenwari	24·9	19·7
Javelin	24·6	17·3
Javelin 48	24·9	18·2
Bencubbin	24·5	22·6
Bencubbin 48	23·5	19·4
Gabo	24·5	17·3
Warigo	23·8	18·3
Gluyas x Hope x Ranee x Ranee (42-79)	28·0	19·9
Gluyas x Hope x Ranee x Rance x Ranee (43-28)	23·2	—
Kenya x 4 Federation (2780)	—	18·3
Gabo x Nabawa x Hard Federation (48-18)	—	16·3
Necessary difference between means for significance at 5 per cent. level of probability.	1·5	2·2

8. YIELD TRIALS OF PEA VARIETIES, 1948.

Date of sowing: May 18th.
Superphosphate: 1 cwt./ac.
Area of plot: 1/33rd acre.
Design: Randomized block of three replications.

Variety	Seed rate lb. per acre	Seedlings per foot	Date of flowering	Mean yield bush per acre
1. White Brunswick	109	2·5	9/8/48	40·0
2. Collegian	120	2·0	8/8/48	40·0
3. Dutch blue	155	3·1	23/8/48	39·7
4. Dun	103	2·6	4/9/48	37·1
5. Greenfeast	155	2·6	17/8/48	27·2

Differences between two means of 4·4 bushels per acre are significant at 5 per cent. level of probability.

9. YIELD TRIALS OF PEA VARIETIES, 1949.

I. *Early sown.*

Date of sowing: June 6th.
Superphosphate: 1 cwt./ac.
Area of plot: 1/33rd acre.
Design: Randomized block of four replications.

Variety	Seedlings per foot	Date of flowering	Mean yield bush./acre
Collegian	2·2	28/8/49	27·5
Collegian x Maori King	2·1	23/8/49	26·2
White Brunswick	2·2	27/8/49	25·8

"z" test not significant.

II. *Late sown.*

Date of sowing: 21st July.
Superphosphate: 1 cwt./ac.
Area of plot: 1/33rd acre.
Design: Randomized block of four replications.

Variety	Seedlings per foot	Date of flowering	Mean yield bush./acre
Collegian	2·9	1/10/49	30·4
White Brunswick	2·0	1/10/49	27·4
Collegian x Maori King	1·8	27/9/49	23·0

Differences between two means of 3·1 bushels per acre are significant at 5 per cent. level of probability.

10. CROP ROD ROW TRIAL, 1949, WAITE INSTITUTE.

Plots: Three rows 18 feet long trimmed to 16 feet, only the middle row being harvested. Five replications.

Sown: 23rd June, rape harvested 5th December, followed by wheat and linseed and finally safflower on 3rd February, 1950.

Seed rates: Wheat 14 gms. per row.
Linseed and safflower 7 gms. per row.
Rape 2 gms. per row.

Results.

Crop	Plants per foot	Date of first flowering	Mean yield lb./acre of grain	Percentage oil in grain on dry basis	Iodine value
Insignia wheat	18	10th Oct.	3,139	—	—
Punjab 5 linseed	52	29th Sep.	756	42·0	189
Russian safflower	7	5th Dec.	1,485	32·5	150
High-oil safflower	7	5th Dec.	1,511	39·0	147·5
Black Argentine rape	23	22nd Sep.	1,249	43·0	105

Notes on diseases and pests.

Red legged earth-mite present on safflower mid-October.

Aphis present on rape mid-October.

Pasmo disease appeared on linseed in the latter part of October and was severe during November and December, greatly reducing the seed yield. No evidence of rust.

Oil determinations made by Defence Research Laboratories, Melbourne.

11. SAFFLOWER VARIETY TRIALS, 1948.

Date of sowing: July 8th.
Superphosphate: 1 cwt./ac.
Area of plot: 1/104th acre.
Design: Randomized block of four replications.

Variety	Seed rate lb./ac.	Seedlings per ft.	Mean yield lb./ac.	Bushel weight lb.	Percentage moisture	Percentage oil on dry basis	Iodine value
Russian	45	3·1	1,665	46·0	7·5	27·5	149
Pusa 2	45	3·1	1,598	48·5	8·0	29	150
Karrar	45	3·0	1,571	47·8	7·5	26	149
Pusa 7	45	2·8	1,557	49·3	7·0	27	149
N.7	60	2·8	1,499	47·5	7·0	28·5	149
Niphad 630	45	2·1	1,431	48·8	7·5	28	149
Egypt	45	2·2	1,382	40·1	7·5	28	148
N.9	60	2·5	1,332	47·3	7·8	25	149
C.P.	60	2·0	1,323	45·0	7·0	29	148
U.S.A. strain	45	2·4	936	47·5	8·5	26	149

Differences between two mean yields of 196 lbs. per acre are significant at 5 per cent. probability level.

Composition of seed and Iodine Values determined by Defence Research Laboratories, Melbourne.

12. FLAX VARIETY TRIAL (A) WAITE INSTITUTE, 1948.

Sown 19th May. Seed rate: 70 lb. per acre. Superphosphate: 1 cwt. per acre.

Variety	Plant establishment seedlings per foot	Date of first flower	Date of harvest	Mean weight of hand pulled straw cwt./ac. Undeseeded	Deseeded	Mean yield of seed bush./ac.
Liral Crown	76	9/9/48	3/11/48	48·5	41·0	6·3
Giza Purple	66	20/9/48	10/11/48	48·9	38·3	9·5
Bison x Liral Prince	58	13/9/48	3/11/48	50·6	39·5	10·8
L.C. x L.C. x Walsh 46-124	58	14/9/48	3/11/48	51·7	41·1	10·0
L.C. x L.C. x Walsh 46-141	69	12/9/48	3/11/48	47·8	36·6	10·7
L.C. x L.C. x Walsh 46-145	53	10/9/48	3/11/48	43·5	35·1	7·9
L.C. x L.C. x Walsh 46-147	65	10/9/48	3/11/48	46·4	37·5	7·0
	Difference necessary for significance at 5 per cent. level of probability.			Not significant		1·18

Rust was very severe appearing on 30th August. The L.C. x L.C. x Walsh crossbreds were particularly susceptible. They were, however, much more resistant to lodging when compared with Liral Crown.

Goldfinches were responsible for a variable loss of seed.

FLAX VARIETY TRIAL (B) WAITE INSTITUTE, 1948.

Sown: 20th May. Seed rate: 70 lb. per acre. Superphosphate: 1 cwt. per acre.

Variety	Plant establishment seedlings per foot	Date of first flower	Date of harvest	Mean weight of hand pulled straw cwt./ac. Undeseeded	Deseeded	Mean yield of seed bush./ac.
Liral Prince	96	11/9/48	30/10/48	44·6	37·8	6·2
Liral Monarch	109	10/9/48	30/10/48	46·8	38·7	6·9
Norfolk Earl	95	8/9/48	30/10/48	44·5	36·8	7·6
Concurrent	87	20/9/48	10/11/48	47·2	37·9	8·2
Wada	95	14/9/48	30/10/48	46·5	37·9	8·0
Stakhanovetz	95	15/9/48	30/10/48	46·2	38·2	7·7
806/3	92	15/9/48	30/10/48	47·9	39·2	7·7
Rembrandt	90	23/9/48	10/11/48	46·8	37·7	8·3
D/83	89	10/9/48	30/10/48	46·1	39·0	8·4
Liral Crown	87	10/9/48	30/10/48	49·4	40·5	8·7
	Difference necessary for significance at 5 per cent. level of probability.			Not significant		1·0

Good evidence of the rust resistance of Wada, Stakhanovetz, 806/3 and D83 was secured.

Severe storms in October resulted in variable degree of lodging, Stakhanovetz being rather worse than others.

Goldfinches were troublesome in October and caused some loss of seed of Concurrent and Rembrandt.

Commonwealth Scientific and Industrial Research Organization

Division of Soils

1. INTRODUCTION.

The Division of Soils of the Commonwealth Scientific and Industrial Research Organization was established in 1929 with headquarters at the Waite Institute. With the extension of the activities of the Division to all States of the Commonwealth it became necessary to establish regional centres at Brisbane, Deniliquin, Canberra, Hobart and Perth. At these places, soil survey and associated laboratory work is undertaken for each region. Chemical, physical and microbiological research is centred primarily at the headquarters of the Division at the Waite Institute which also acts as the administrative centre for regional activities as a whole. The regional centres are, however, being strengthened to enable more laboratory research to be undertaken on problems of significance within the regions.

Work is proceeding throughout the Commonwealth on the mapping of soils and the determination of their properties. The long term objective is to obtain basic information on the soil resources of Australia. The more immediate objective in some of the field work in hand in all States is related to assessment of areas proposed for land settlement. Co-operation with State and Commonwealth authorities has continued in this work and in South Australia a number of areas have been covered by soil surveys in Kangaroo Island and in the South-East to assist in land settlement proposals.

Post-war interest in housing has created a demand for information on soils as they affect foundations of houses. A programme is in hand for identifying and locating soils which give trouble as foundation material and for determining the behaviour of these soils with seasonal changes in water content. A mobile laboratory has been set up to assist the examination of soils in the field. There has been close co-operation with the South Australian Housing Trust on that part of the work proceeding in the Adelaide suburbs.

For some time the Division has been distributing cultures of Rhizobium for legume seed inoculation on a commercial scale. The demand for these cultures by South Australian growers had increased to such an extent as to impose a strain on the Division's facilities. The Waite Institute has now accepted responsibility for distributing these cultures to farmers but the Division of Soils will continue, at least for the present, to maintain the reference collection of cultures which it has developed. In this and in other ways close co-operation has been maintained with the Waite Institute.

2. SOILS SURVEY AND PEDOLOGY SECTION.

During the past two years, 1948–1949, the survey and pedological work of this Section has proceeded on the basis of both detailed and reconnaissance surveys, most of the projects being in some way connected with the requirements of government authorities who are concerned with the settlement of ex-servicemen on the land. Since these projects are concerned with varied forms of primary production, the associated soil work has ranged from detailed soil surveys of areas chosen for irrigated horticultural settlements to broad scale and soil association surveys of areas whose potential for settlement is partly determined by the findings of the soil investigations. The results of the soil surveys on areas finally selected for settlement are used both as a basis for sub-division into holdings and layout designs therein and as a factor determining the nature of the fertility trials which may be required to test the likely productivity of the areas.

Surveys in South Australia.

The Northern Marginal Lands survey has been brought to completion as two units of work. The first comprised a reconnaissance survey of approximately 2,500 square miles embracing what is known as the Northern Marginal Lands Area. The second unit comprised a detailed survey of the Hundreds of Willochra, Coonatto and Pinda in County Frome, and this survey was accompanied by associated investigations of land use and the incidence of soil erosion in the area.

Soil surveys of a number of units of land on Kangaroo Island have been undertaken primarily for the use of land settlement authorities. The first unit surveyed comprised the Hundred of Seddon and part of the Hundred of MacGillivray, and this survey, apart from its usefulness in land settlement activities, confirmed the general principles laid down by earlier work of the Division concerning the nature and distribution of lateritic soils particularly in relation to topography and degree of dissection of the landscape. Two further units were subsequently surveyed, these together comprising parts of the Hundreds of Duncan and Newland.

During 1949 a start was made on an intensive soil survey of the horticultural land in the Barossa Valley and contiguous horticultural areas. This survey which was commenced in a modest way will continue for at least two further years. It is too early as yet to indicate any results of the survey but they will be primarily concerned with pedological and land use studies of soils used primarily for horticultural purposes, vines and stone fruits being the major crops.

In the latter part of 1949 a soil survey was commenced in areas of the middle South-East lying in the country east of Kingston. This survey is designed to help land settlement and drainage authorities in deciding the nature of land settlement best suited to this area and in what way the soils will need to be modified by drainage to attain maximum production.

Surveys beyond South Australia.

Apart from the work in South Australia, soil surveys and related investigations have been undertaken in all States and in Northern Australia.

In Western Australia, surveys of a detailed and reconnaissance character have continued in the forested areas of the South-West portion of the State where continued effort is being expended in the establishment of dairy and sheep raising farms. Some attention is also being paid to the less forested areas in the slightly lower rainfall districts where fertility problems are quite apparent, but this work is more long-termed in its objective than that mentioned above. In both regions the soils are of a lateritic and post-lateritic character with which is naturally associated a complex of soil fertility problems.

In Queensland, a soil survey of the Lower Burdekin River Valley has been continuing since early 1948. Despite difficulties, steady progress has been made and a further year's work should see this investigation completed. It aims to define the soil types in the Valley area in relation to topographical features such as levee banks and flood plains, and to lay a foundation for exploratory land use under irrigation by water conserved in structures designed to provide water for irrigation and at the same time give some measure of flood control.

In New South Wales both the Lismore and Hunter Valley surveys have been concluded. In addition further units of country in the Riverina have been covered by soil surveys of different detail adding to the rapidly growing bulk of knowledge about the irrigated soils in that region. From that knowledge and from continuing investigations has emerged a theory concerning the genesis of these soils in this area. Evidence has been brought forward to support a theory that the present soils are largely associated with an alluvial landscape which owes its parent material and topography very largely to a system of prior streams, and that the present active stream pattern of the Riverina region is not of particular significance with regard to the soils except on the immediate flood plain areas.

In the Macquarie Region in North Central New South Wales a soil survey of a reconnaissance character has been completed and this survey was followed by a detailed survey of two areas, one of which is likely to be selected as an irrigation area. These broad and detailed surveys were done primarily at the request of the Regional Development Division in New South Wales and have resulted in the mapping in a large area of soils, whose future land utilization will depend both on the provision of water for irrigation and on forms of dry land farming. The type of survey developed here, which shows the soils as associations of Great Soil Groups, is applicable in a useful way to the appraisal of soils in any large region.

In Victoria in the western districts, a soil survey of the Coleraine District was undertaken both as a pedological study and to find basic information concerning the prevalence of landslip and gully forms of erosion in this area. The district comprises a dissected tableland with lateritic soils on the flat areas on top of the tableland and a variety of soils on the slopes and in the valley bottoms. It was shown that the land-slips are a perfectly natural phenomenon associated with the water-table and steeper sloping sides of the tablelands and that the gullies in the valley bottoms had an origin associated with a past era of cultivated land-use.

In the same State in the Murray Valley Irrigation Area a further survey of country with a part irrigation right was undertaken. This area lies in

the vicinity of Nathalia and together with the earlier work undertaken on the two other adjacent areas, will ultimately be presented as one complete study of the soils of the irrigation area. Both pedological and land use studies were made of the soils, particularly with regard to the selection of those soils best adapted to irrigation.

In Tasmania the programme of soil work has been interrupted for some time but a start has been made on the integration of smaller units of survey work formerly undertaken both in the Launceston Tertiary Basin and in the Derwent Valley. In both these areas land settlement is an important feature of present agricultural activities and the soil, geography and pedological studies emerging from the integration of the smaller surveys should be of considerable use in the development of a sound land-use policy in these parts of Tasmania.

In Northern Australia, the North Australia Survey Party completed a period of field activity concerned with the mapping of soils, vegetation and topography of the Barkly Tablelands in 1948. This, together with the previous year's work, completed investigations of that area. During 1949 a similar investigation was commenced in the Victoria River country south and east of the Darwin-Katherine area. A further period of field work will be required to conclude this survey.

3. SOIL CHEMISTRY SECTION.

Chemical investigations on the soil samples collected during the field survey of the Northern Rivers District of New South Wales have been continued and are now nearing completion. Attention has been concentrated on the red loam types but other soils in the survey area have also been studied. In addition to the routine chemical description of the type profiles detailed studies have been made of the variability of the exchangeable cations, organic carbon, and phosphate. For this purpose a proportion of all samples examined in the field during the earlier grid survey for soil reaction was retained for subsequent laboratory studies. Variability in each of the above soil properties was considerable from spot to spot and was similar to that disclosed in the earlier survey of soil reaction. Much information has been obtained on the cation exchange capacity of this group of soils and this has been supplemented by titration curves of characteristic soils. A fractionation of the calcium, magnesium, sodium and potassium occurring in the surface and some deeper horizons of these soils has also been carried out. The amounts present are mostly low; more than half of the total calcium of the soil is present in an exchangeable form.

Following the completion of the soil reaction survey of the Field Station at Barooga, N.S.W., of the Division of Animal Health, several sample sites were established to study possible seasonal trends in soil pH. Regular monthly samplings, over a period of twelve months, showed that variability from spot to spot, even within relatively small areas of the few square feet of each sample plot, was greater than any seasonal change. The changes in reaction from spot to spot in an apparently uniform area of soil are associated not only with changes in the proportion of exchangeable hydrogen to exchangeable metal ions but also with changes in the exchange capacity of

the soils. In a parallel investigation carried out on Urrbrae loam at the Waite Agricultural Research Institute, seasonal trends of the order of 0·15 pH unit were discernible although partly masked by the spatial variations which occurred even in small areas. In each season an increase in the pH of Urrbrae loam occurred after the opening rains in April and May; the pH then slowly fell, to return to the original value in the succeeding dry season (January-April). In this soil type the spatial variation of the exchange capacity of the soil could be correlated with variations in clay and organic matter. A similar correlation could not be established at Barooga but in some of the heavier soils at that locality differences in soil reaction could be associated with differences in exchangeable sodium.

Factors controlling the availability of the micro-elements in soils have continued to receive attention and work is in progress on the fractionation of manganese and copper compounds in soils and on factors affecting the uptake of these elements by plants. Earlier work on the uptake of copper and molybdenum by subterranean clover has been continued. An examination of plants at different stages of growth showed only minor changes in the proportion of copper in the dry matter throughout the growing season. There was, however, a steady decline in the proportion of molybdenum in the plant as maturity was approached.

Continued progress has been made in the development of quantitative spectrochemical techniques for soils and plant material. A comparator-densitometer, which was specially designed for use with the complex spectrograms of soils, has been constructed in the Division's workshop. This instrument combines many features not available on commercial instruments and, in use, it has proved itself particularly well adapted for both routine and special measurements of density. Routine determinations of the minor metallic components of soils and plant samples can now be carried out with a precision generally better than ± 10 per cent. for a single determination. Comparison of the chemical and spectrochemical methods for the determination of molybdenum in 130 samples of plant material (in amounts varying from 0·01 to several parts per million) gave a correlation coefficient of 0·99 between the two methods. Investigations of such matters as background correction and interaction of elements in the arc column have been the subject of much attention. An entirely satisfactory correction can now be made for the intense background in soil spectrograms. The method of quantitative analysis, which involves an addition to the sample of a known amount of the element to be determined gives good results when applied to soils. Spectrochemical methods of analysis are usually associated with the determination of elements present in the sample in low to very low concentrations. However, investigations have shown that it will be practicable to determine some of the major constituents of soils by suitable spectrochemical methods. A start has been made on the spectrochemical examination of typical examples of the "Great Soil Groups" occurring in South Australia, to determine the distribution of the less common metals both in the different soil types and in the different horizons of the profiles.

Experience with the air-acetylene flame method of spectrochemical analysis has confirmed the value of this method in the determination of the individual exchangeable cations in soils. The method has been in use con-

tinuously in the routine examination of type survey samples. The method enables the simultaneous determination of several different elements in the one small sample of material. Because of the unique suitability of the Division's equipment, assistance was given to a local medical investigator by carrying out a series of analyses of blood plasma for him, the amounts of sample available being too small for ordinary chemical methods. These analyses enabled him to establish the previously unsuspected part played by a subnormal concentration of sodium in the blood serum in the infant malady known as Pink Disease and led to a simple and effective cure for that disease.

The routine chemical examination and description of soils collected during soil surveys has continued, approximately 1,500 samples being examined each year. It has been possible to examine many of these in greater detail, to assist in the elucidation of the pedological problems. Such analyses have included detailed analyses of the clay fraction, analyses of hardpans, ironstone gravels and manganiferous concretions found in soils and the examination of various parent materials from which soils have been formed. A large series of gypsum samples from deposits in the Wakool Irrigation Area was also examined. Soils from pine plantations at Moss Vale, N.S.W., were examined for their phosphorus status. These soils were very low in available phosphorus. They also had an extremely high phosphate fixation capacity and this probably accounts for their lack of response to ordinary applications of superphosphate. Regional laboratories have now been established at Brisbane, Perth and Hobart. In addition to investigations of local interest these laboratories are now undertaking the examination of all type samples collected from surveys within those regions.

4. SOIL PHYSICS SECTION.

(A) Soil Structure.

There appears to be a widespread awareness of the importance of soil structure in relation to maintenance of fertility and the establishment of pastures as well as its effect on permeability to water. The Division has been engaged on aspects of this research.

Methods for examining soil structure have been investigated in connection with work being done on the maintenance of good physical conditions for crop growth. The object has been to introduce refinements which will help reveal minor differences in the stability of structural aggregates in water. In the course of this work, the effects of time of shaking in water, flood and capillary wetting, and apparatus characteristics on the measurements have been examined and a modified procedure adopted.

The structure of soils from Lismore, New South Wales, has been examined and the high stability of the red loam soils there has been confirmed. Other work has been undertaken at Deniliquin, N.S.W., in relation to pasture establishment on clay soils and at Griffith in relation to reconditioning of old irrigated orchard soils.

A drop-shatter technique has been developed to study the mechanical stability of dry soil. The size distribution is obtained, after dropping soil from specified heights on to a hard surface, by the use of a rotary sieve. This distribution has been found to conform with the Rosin-Rammler rela-

tion for the size distribution of shattered brittle solids. The breakage by this technique has been found to correspond to that obtained by the application of the manual forces in a field descriptive method used by this Division. It is expected that this new procedure will assist in the characterization of soils.

(b) Soil Colloids.

X-ray studies have continued on the clay minerals present in soils. The group of brown solonized ("mallee") soils was selected for the initial project and the research is approaching completion. It has been found from X-ray diffraction and associated investigations that illite is consistently present in mallee soils and in fact represents about 75 per cent. of the clay minerals of these soils. The samples being used in these X-ray studies came from representative "mallee" soils in Victoria, South Australia and Western Australia.

In this work a method is being used which permits the approximate determination of the relative proportions of each mineral occurring in a sample. The technique is empirical and consists in preparing various mixtures of standard clay minerals the patterns of which are compared with those of the soil colloids. Since size and degree of perfection of the crystals are unknown factors that also affect intensity of line development the method is only semi-quantitative. The samples of soil colloid are treated with glycerol to intensify the diffraction lines of one of the common minerals—montmorillonite. Without this treatment the lines may vary in intensity depending on the water content of the colloid. Additional information regarding identification of the colloids from mallee soils has been obtained by measurement of the adsorption of water vapour and the dehydration of the colloids upon heating.

(c) Water entry into Soil.

A number of projects dealing with the entry of water into soil have been concluded. These include work undertaken on the principles of downward flow of water into soil on which a paper has been published. Tension of soil water was measured during the application of water to the surface and subsequently during drainage into dry uniform soil. It was found that in the wetted soil, tensions ranged between 4 and 18 cm. in different soils during application. During subsequent drainage (after application of water had ceased) a gradient in tension was observed opposing downward flow. Mean values of tension in the wetted soil ranged between 35 and 90 cm. in the different soils at a stage corresponding (in the laboratory) to field capacity. Field trials had earlier given similar results under less controlled conditions.

Small sprayed and flooded plots are commonly used to determine the infiltration characteristics of soils. They provide useful comparative data but, because of the lateral movement of water by seepage beyond the limits of the plots, infiltration rates obtained in this way are not representative of large areas wetted by rain or irrigation water. It has been found that relatively large plots are required, greater than 10 feet in diameter in most soils, before this lateral spread is reduced to negligible proportions. It is not

always practicable to use such large plots as these and methods for preventing or correcting for lateral movement have been investigated. Wetted buffer zones surrounding the test plot were found to be effective with spray applications but not with flood applications. A correction factor was worked out which when applied to results from small unbuffered plots made most of them virtually independent of size of plot and the results more applicable to large wetted areas. This factor is based empirically on the fraction of the total applied water found immediately below the test plot at the conclusion of the application.

A paper dealing with the effect of cultivation practices on infiltration of water into some horticultural soils has been published. It was found that little change had occurred in infiltration characteristics of sandy soils at Berri, S.A.

An investigation of the physical properties of soils of the Lower Burdekin Valley, North Queensland, has been commenced in relation to the soil survey programme proceeding in that area. A series of infiltration measurements have been undertaken on various soil types in order to help their assessment for development under irrigation. This work is to be extended and other physical properties of the soils are to be examined.

In connection with soil survey work undertaken in the neighbourhood of Lismore, N.S.W., an investigation has been made of the infiltration characteristics of soils in that district. This has shown that the rate of water entry into the red loam soils when initially dry is high for soils of such high clay content. Many farmers in the district consider that the quantity of water entering these soils has decreased in recent years and they have attributed this to "sod bound" conditions in the paspalum pasture. The infiltration trials did not show that the pasture cover had this effect. However, it was observed at the time this work was carried out that the soils under paspalum had a high water content which was probably due to the low transpiration rate of paspalum during its dormant period from May to September. This would be sufficient to account for low infiltration rates during that part of the year.

(d) Evaporation of Water.

Co-operative work has been undertaken with the University of Adelaide at the Waite Institute on the use of the Piche evaporimeter. The effect of wind has been studied and a relation worked out between weekly evaporation at the Waite Institute from a standard tank evaporimeter and from a Piche evaporimeter after correction for the effect of wind.

(e) Measurement of Water Content of Soils.

For many purposes it is desirable to be able to follow changes in the water content of soils without the necessity of disturbing the soil every time samples are needed. This is particularly the case in the investigations being carried out in relation to house foundations. It has been found convenient to do this indirectly by measuring the electrical conductivity of gypsum blocks embedded in the soil. The blocks in present use have certain disadvantages and efforts have been made recently to improve them.

A pressure device for controlling the water content of soil samples is being used in connection with the calibration of gypsum blocks for interpretation of electrical conductivity in terms of water tension and water content. A new resistance bridge for measurement of gypsum block resistances in the field has also been constructed. This bridge represents a considerable improvement over equipment used until recently. An account of the instruments now adopted by the Division for these measurements is being prepared for publication.

(f) Seasonal Changes in Water Content of Soils.

A problem of some magnitude in roadway or airport design and in foundation engineering is the determination of the water content of the soil when water entry is prevented by the nature of the surface cover, and water removal by the action of plant roots is not significant. To study this problem, moisture measuring instruments have been established under a number of small buildings in the suburban areas of Melbourne and Adelaide and under a roadway pavement near Adelaide. In an attempt to determine the importance of temperature in providing the forces responsible for water movement under such conditions, a larger and more elaborate installation has been established under a building on the premises of the Building Research Division, C.S.I.R.O., at Highett, Victoria. Another large installation of moisture and temperature sensitive elements will be made under a main runway at the Essendon airport, where the uniformity of the soil and the large extent of the covered area provide ideal conditions for a study of water movement. This will be undertaken in co-operation with the Department of Works and Housing.

In conjunction with trials on covered sites, measurements have also been made of seasonal fluctuation of water content in soils exposed to normal rainfall and evaporation and carrying normal grass cover. In Adelaide where some of the work has been done co-operatively with the University of Adelaide, it has been found that, at depths down to 6 feet, the soil is annually dried down to the wilting percentage and wetted up to a tension of about 300 cm. Except near the surface, this corresponds to a relatively small change in water content. Information is available for twelve sites and it is being prepared for publication.

(g) Shrinkage and Swelling of Soils.

As a first approach to the study of the mechanism of shrinkage and swelling of clay soils, apparatus has been developed to measure the volume changes which occur throughout the soil profile. Installations of this type of apparatus have been made on typical soils of Melbourne and Adelaide, alongside the moisture and temperature installations mentioned above. Data from these instruments may be interpreted to reveal the relationship between volume change and water content change, and between volume change and soil moisture tension in the undisturbed soil.

The actual movements recorded within the various profiles are of practical significance in relation to the design of building foundations. Vertical movements of two inches have been recorded at the soil surface on some soils at Adelaide. The vertical movement in this soil is not reduced to a

safe value for stability of the building until a depth of more than six feet is reached.

Records have been kept for a period of up to two years on most sites, and these data are now being prepared for publication.

(h) Soils in Relation to House Foundations.

Soil surveys of a number of building estates have been carried out to provide information regarding foundations for the Housing Trust of South Australia and the Housing Commission of Victoria. As a result of this work and of field examinations elsewhere in the suburbs, it has been possible to prepare a reconnaissance map of the soils of Melbourne. A similar map of the soils of Adelaide suburbs is in preparation.

The purpose of the map is to distinguish the areas in which soils which are basically different in physical and engineering characteristics may occur. It was found that the dominant factor affecting the physical properties of the soils near Melbourne, is the underlying geological formation. The association of soil type with parent material and topography assisted the mapping materially. Seven soil associations are mapped and within them fifteen soil types are defined.

This map is now being used as the basis for the field programme of determining the physical characteristics of the soils of Melbourne, particularly with a view to understanding their relation to building foundations.

A start has been made on the preparation of a similar map for the suburban areas of Adelaide. Here the soil pattern is more complicated and no geological plan is available. The Mines Department of South Australia is at present preparing such a plan and geological and soils officers are co-operating closely on the Adelaide work.

5. SOIL MICROBIOLOGY SECTION.

The main work of the Section has centred around studies of the bacterial genus *Rhizobium* and the symbiotic fixation of nitrogen in association with leguminous plants. A study has been made of the organisms associated with the most important pasture legumes under South Australian conditions and strains most suitable for seed inoculation selected and characters studied.

During 1948, at the request of growers, a total of 1,849 bacterial cultures were sent out, mainly for lucerne (773), subterranean clover (594) and field pea (313). During 1949 a total of 2,464 cultures were distributed, including lucerne 964, subterranean clover 1,141 and field pea 122. The demand for cultures continues to increase at such a rate that a severe strain has been imposed upon the facilities of the Division of Soils, to cope with the numbers required, and arrangements have now been made for the University of Adelaide to accept the responsibilities of commercial culture distribution.

The main reference collection of rhizobial cultures still remains with the Division of Soils and about a hundred strains are periodically checked for their retention of ability to infect suitable host legumes. So far it has not been possible to reliably correlate cultural characteristics with abilities to tolerate extremes of temperature, acidity and alkalinity with powers of infectivity, so that contamination with culturally similar non-nitrogen fixing

organisms such as *Agrobacterium radiobacter* is not readily disclosed except by test of infection. Moreover, some strains show changes in infectivity and effectiveness under prolonged storage on artificial media. Some strains are relatively "unstable" and show frequent changes and tend to give irregular results whilst other strains show a slow gradation towards greater or less effectiveness. Hence regular checkings are essential in the maintenance of a reliable type culture collection.

An investigation of techniques and methods suitable for the commercial distribution of viable bacterial culture of *Rhizobium* and for maintenance of the reference culture collection has led to a number of innovations in handling, packing, storage and distribution of cultures so that a large number of cultures can be promptly handled with maximum efficiency from limited facilities.

During 1947 a programme of investigations was commenced into establishment of inoculated strains of *Rhizobium* in field soils in competition with the indigenous population. Serological methods have been utilized to identify the bacterial strain initiating the nodule and suitable serologically stable strains with distinctive antigens used as inocula. With use of a suitable strain, fifty per cent. and more of the nodules were derived from the inoculated strain, but such strains showed considerable differences in their ability to invade and establish themselves as part of the active field microflora. A survey has also been made of the distribution of specific antigens of *Rhizobium trifolii* in association with red and subterranean clovers, but although striking differences were found in the proportions of strains containing specific antigens found in separate localities, no consistent differences between large districts were established.

Organisms similar in character to *Bacillus polymyxa* have been isolated from a number of surface and clay subsoils with a tendency to show mottling or glei formation in lower horizons. These organisms are capable of reducing ferric oxide in both free and fixed forms to the soluble ferrous form with accompanying decolorization of various shades of reds and browns to greys and white. In pure culture the organisms are capable of iron reduction when supplied with glucose as energy material, but the reaction is rarely as vigorous as that of mixed cultures of organisms. The occurrence of these organisms is not limited to soils showing mottled horizons or to subsoils only, but they are widely distributed in many soil horizons and types, and only under exceptional circumstances does sufficient reduction of iron occur to give visible mottling of the profile.

6. GUAYULE RUBBER.

As stated in the report of 1943–47 these investigations, since 1945, have been carried on as an activity of the Council for Scientific and Industrial Research (now Commonwealth Scientific and Industrial Research Organization). This has involved the continuance and maintenance of the plots including irrigation, modification of irrigation programme, reduction of the size of certain of the irrigated areas to render them more satisfactory for sampling purposes, etc. The latter procedure was partly necessitated by the request of the S.A. Department of Lands and Irrigation for the return

to that Department of any land not essential for the furtherance of the project, the non-essential portion being relinquished in January, 1948. The Lands Department further granted the use of the fields still under guayule until 30th June, 1949, at which date it was decided to terminate the project. The ultimate transfer of all land back to the Department took place as from approximately that date. The ten plots remaining under observation, referred to in the report of 1943–1947 continued to make growth to the end of the project at the date mentioned above. However, when approximately 5½ to 6 years of age plants in all areas showed signs of senescence in that appreciable amounts of dead and dying wood appeared on them.

Progressive samplings of all plots were continued, as in previous years until 30th June, 1949, weight increments of leaves, stems and roots, as far as it was possible to recover the latter being determined as before. These samples were also chemically analysed for acetone soluble substances (resins, etc.) and rubber, total rubber in the plant being derived from the data collected for its constituent parts. Early in 1948, the non-irrigated plants at Loveday, Section 231 (U.S. selected seed strain) contained 9·7 per cent. rubber and 49 gms. per plant; those at Loveday, Section 558 (irrigated) and from the same seed strain contained 8·7 per cent. rubber and 108 gm. per plant; at Loxton (also irrigated) the U.S. selected seed strain gave plants containing 8·2 per cent. rubber and 111 gm. per plant; non-irrigated plants at Morphett Vale contained 9·6 per cent. rubber and 80 gm. per plant.

At the final samplings from the same plots in June, 1949, although the plants were approximately 18 months older their rubber contents were not at their maxima. This was on account of the accumulation of dead wood, owing to the senescence of the plant, mentioned above.

The maximum rubber contents were found, for the above plots as follows. At Loveday, Section 231 (not irrigated) on 26/1/49 the plants contained 9·5 per cent. rubber and 65 gm. per plant; at Loveday, Section 558 (irrigated) on 26/10/48 the rubber content was also 9·5 per cent. but with 133 gm. per plant; at Loxton (also irrigated) on 29/4/49 the plants contained 10·6 per cent. rubber and 164 gm. per plant. At Morphett Vale (not irrigated) on 29/6/49 the rubber content was 11·8 per cent. and 95 gm. per plant. From the unselected Canberra seed strain the plants grown at the S.A. Government Orchard at Berri which were initially irrigated and later grown under natural rainfall the highest rubber content for that site was reached on 25/1/49, only 2·46 per cent. and 51 gm. being found.

The field work and sampling of this project was terminated at the end of June, 1949, and the remainder of the chemical analyses have also been completed. The data collected over the whole period since commencement of sampling are now being collected together and prepared for publication as a C.S.I.R.O. investigation.

Oenological Research

Oenological Research at the Waite Institute is conducted under a special Committee of the C.S.I.R.O. representative of the Wine Industry and the scientific disciplines concerned. It is financed in equal parts by the Australian Wine Board and the Federal Treasury.

1. Sherry Investigations.

The investigations on sherry to which reference was made in the report for 1943–1947 were continued. Information concerning the effects of oxygen supply, sugars and organic acids on the metabolism of the yeast has been obtained by using suspensions of non-proliferating cells as well as growing cultures. It has been found that vigorous growth of these yeasts on wines is usually accompanied by a marked fall in the oxidation-reduction potential of the wines and in many cases results in restricted and irregular accumulation of acetaldehyde and development of the desired sherry flavour and aroma. On the other hand, conditions which favour a moderately vigorous film growth frequently result in a superior product. Control of temperature and oxygen supply has been shown to have an important effect on the quality of the product and the influence of these and other factors is being further studied.

2. Collection of Yeast Cultures.

Four additional strains of the sherry yeasts have been obtained from the University of California collection. They have been compared with strains already in our collection, but the new strains appear to be inferior to the best of those previously studied. Strains which have been selected as suitable for the production of sherry, on the basis of laboratory trials, have been supplied to a number of winemakers in response to requests for such cultures.

At the request of the Australian Wine Board, the Committee has extended its research programme to the establishment of a general collection of tested strains of yeast, in addition to those suitable for the production of sherry. About 90 strains of wine yeasts collected from local and overseas sources were available at the end of 1949. Examination of them and the development of laboratory techniques to test their suitability for different conditions has been commenced.

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